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Technical Report

No. 13480

COMBAT VEHICLE IDENTIFICATION SYSTEM
(CVIS)

FINAL
SCIENTIFIC AND TECHNICAL REPORT
CONTRACT DAAE07-85-C-R109
DECEMBER 1989

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1.0 INTRODUCTION

This final technical report, prepared by General Dynamics Land Systems for the U.S. Army Tank-Automotive Command (TACOM), under contract DAAE07-85-R109, describes the design, development, and field testing of an Identification Friend or Foe (IFF) system for the M1 Abrams main battle tank. The basic concept of this system involves utilizing the laser rangefinder (LRF) of the M1 as a means to interrogate potential targets, to cooperatively determine their identity through a computer controlled pulse code sequence.

2.0 OBJECTIVE

The primary goal of this contract was to design an IFF system utilizing the M1 LRF production hardware and demonstrate the concept feasibility in the field.

3.0 CONCLUSIONS

The Combat Vehicle Identification System (CVIS) represents an off-the-shelf, inexpensive solution to the current IFF problem. IFF with the current ND YAG LRF, is possible out to the operational range of the LRF. The major limitations of this system are:

- The system concept is active/cooperative and by its very nature will only positively identify friendly systems equiped with the CVIS transceiver system. In other words, the system will only positively identify friends; foes are identified by default. All active/cooperative systems (i.e., Mark 24 transponder) share this flaw, as they only detect a failure to return the correct reply; incorrect or no reply is judged to be a foe.

- The system will only function properly if the gunner can maintain "lock on" or track of his respective target for a minimum of 3 seconds.

4.0 RECOMMENDATIONS

- Since no true IFF candidate system is currently available or easily integratable, the CVIS system should be optimized and implemented as a near-term best solution to the IFF problem.

- A procedure to prevent ballistic superelevation offset of the sight during the IFF sequence must be developed to eliminate IFF errors.

- The repetition rate of the laser should be increased to minimize the duration which the gunner must maintain lock on the target.

- The control panel of the CVIS unit should be changed to eliminate the diagnostic and built-in test switches, a simple 3-position switch (code A-B-C), and two indicator lamps (red/green) would suffice.

- The CVIS retroreflector assembly has been fabricated using gold first-surface mirrors. This provision will allow the system to reflect either a YAG or CO_2 LRF or any other wavelength.

5.0 DISCUSSION

5.1 BACKGROUND

The initiation of this effort stems from available means to identify ground combat vehicles as friends or enemies from a ground position. The objective was to develop such a system for the M1 main battle tank that would maximize the use of current tank hardware and utilize only off-the-shelf type components for the add-on systems.

The system chosen to exploit the IFF requirement was the M1 LRF because of its very desirable qualities such as a narrow beam for covertness, high power for good range, ease of pointability at long distances, since it is already aligned to the Gunner's Primary Sight reticle.

The combat vehicle identification operation is similar to the operation of a standard LRF. The gunner or commander sights on the target vehicle and fires the LRF, while in the IFF mode. The target vehicle contains a transceiver that is preset to one of several code sequences. On receipt of a correct interrogating pulse code, the target vehicle will reflect the preselected pulse codes back to the LRF interrogator, thus identifying itself as a friend. The transceiver on the interrogator vehicle receives the pulse codes, confirms that they are the correct response, and identifies the target vehicle as a friend to the gunner or commander.

In terms of simplicity, the retroreflector approach has strong merits. In this scenario, the interrogating vehicle first sends two pulses to the target. If the code is valid, the vehicle will anticipate two more pulses and respond by opening and closing a retroreflector in the correct reply sequence. The interrogator will then identify this sequence as high-intensity reflections different from a normal diffuse reflection. It will then look at the high versus the diffuse intensity as a binary 1 versus 0, and check for proper coding. The exact details of this code sequence are completely explained in section 5.22, "IFF Coding".

5.2 TECHNICAL REQUIREMENTS

The M1 and M60 rangefinder systems are completely different in their methods of operation. Although both systems employ lasers, they are of different types. The M1 has a Dye Q-switched Neodymium YAG laser which radiates at a wavelength of 1.06 um, while the M60 has a complex mechanically Q-switched Ruby laser radiating at a wavelength of .68 um. This difference in wavelength, combined with the complexities associated with the M60 beam transport optics, make a mutually compatible system impossible. Therefore, since the M1 laser rangefinder utilizes a simpler but more technically advanced design, it was chosen as the preferred candiate.

5.2.1 OPERATIONAL DESIGN RANGE

The CVIS system was designed to operate at ranges in excess of 2000 meters. In order to facilitate this requirement, calculations were performed to determine the laser peak power, laser energy incident at the downrange target, required retroreflector cross section, and required detector sensitivity at the interrogator system and target system. These calculations assume generally poor atmospheric conditions.

The calculations in Figure 5.1 depict the beam divergence and atmospheric attention for the LRF. The assumption of 10% transmission per kilometer assumes conditions poor enough to make other laser beam attenuating factors insignificant.

The detectivity of the event is then calculated in Figure 5.2 utilizing the half-power point of the LRF pulse, as a conservative estimate for the detector requirements.

The results of this basic analysis, combined with a temporal power spectral density analysis of the LRF beam, has been summarized in an overall system detection requirement as follows:

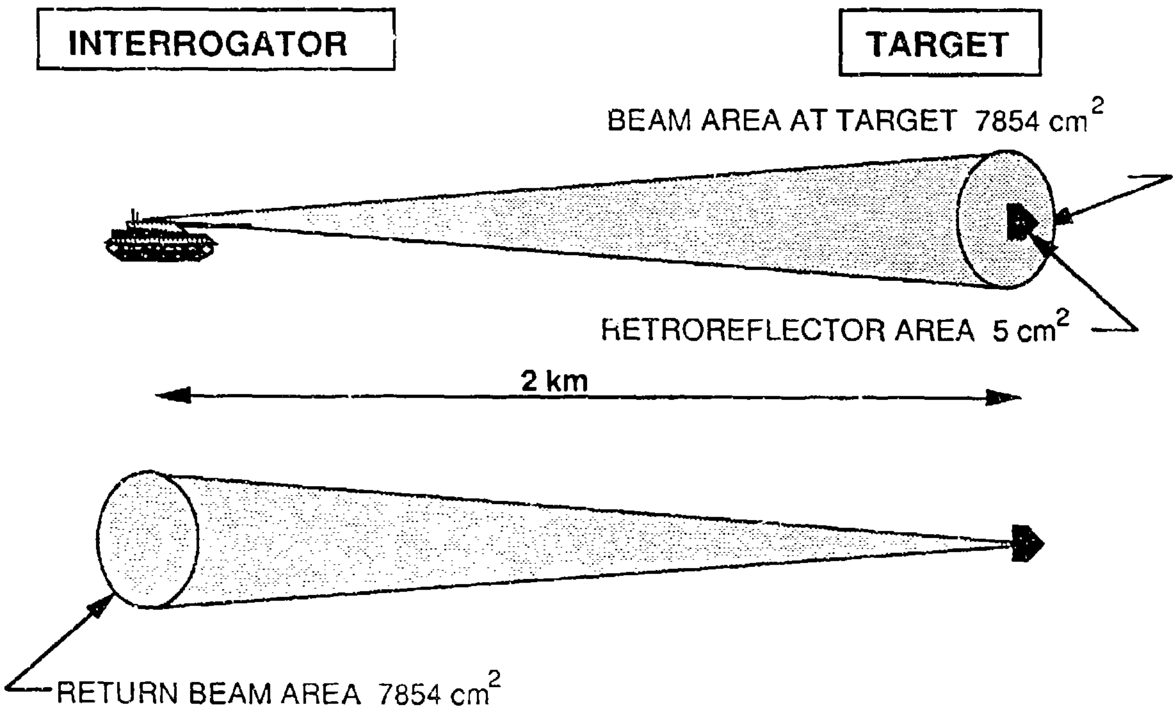
- Fournier analysis at LRF pulse indicated bandwidths $\leq$ 125 MHZ.
- Range/energy calculations showed anticipated energy

LRF SPECIFICATIONS

40 mJ PULSE
8 ns PULSE LENGTH
0.5 mrad BEAM DIVERGENCE
λ = 1.064 um

ASSUMPTIONS

20 mJ AVG.PULSE ENERGY
2.5 cm diameter RETROREFLECTOR
0.1/km ATMOSPHERIC TRANSMISSION @1.064um



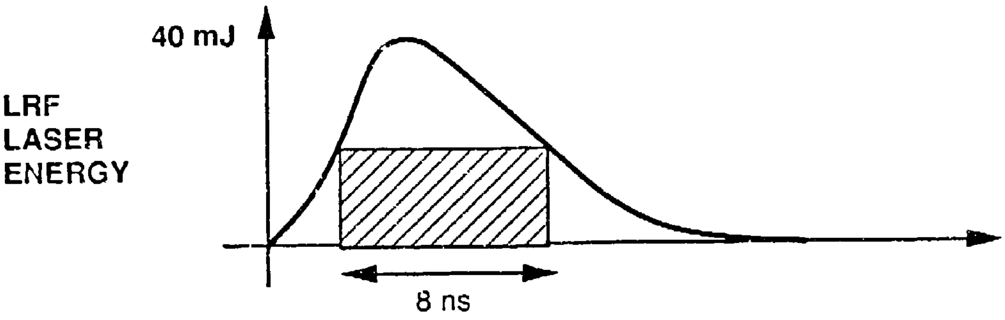
ATTENUATION AT TARGET

$$\left(\frac{0.1}{\text{km}}\right)^2 \left(\frac{1}{7854\ \text{cm}^2}\right) = \mathbf{1.2732\ E\text{-}6}$$

ATTENUATION BACK TO INTEGRATOR

$$\left(\frac{0.1}{\text{km}}\right)^4 \left(\frac{5.0\ \text{cm}^2}{7854\ \text{cm}^2}\right) \left(\frac{1\ \text{cm}^2}{7854\ \text{cm}^2}\right) = \mathbf{8.106\ E\text{-}12}$$

Fig. 5.1 LRF Atmospheric Attenuation



AVERAGE POWER $\left(\frac{20\ \text{mJ}}{8\ \text{ns}}\right) = \mathbf{2.5\ MW\ Avg.}$

AVERAGE POWER DENSITY AT TARGET $(2.5\ \text{MW})\ (1.2732\ \text{E-}6) = \mathbf{3.18\ \frac{uW}{cm^2}}$

AVERAGE POWER DENSITY AT INTEGRATOR $(2.5\ \text{MW})\ (8.106\ \text{E-}12) = \mathbf{20.265\ \frac{uW}{cm^2}}$

RESPONSIVITY DETECTOR AREA

$$\left(\frac{0.28\ \text{A}}{\text{W}}\right)\left(\frac{5.1\ \text{mm}^2}{7854\ \text{cm}^2}\right)\left(\frac{1\ \text{cm}^2}{100\ \text{mm}^2}\right)\left(\frac{3.8\ \text{W}}{\text{cm}^2}\right) = \mathbf{54\ mA}$$

$\therefore$ ***DETECTABLE AT TARGET***

DARK CURRENT

$$\left(\frac{0.28\ \text{A}}{\text{W}}\right)\left(\frac{5.1\ \text{mm}^2}{7854\ \text{cm}^2}\right)\left(\frac{1\ \text{cm}^2}{100\ \text{mm}^2}\right)\left(\frac{20.265\ \text{uW}}{\text{cm}^2}\right) = \mathbf{290\ nA}$$

$\therefore$ ***DETECTABLE BUT MARGINAL***

Fig. 5.2 Detectability Requirements

densities to be 3.8 watt/cm squared at the target vehicle and 290 nanowatts/cm at the interrogator for the worst case analysis.

- The target vehicle detector required moderate sensitivity and high-damage threshold, with extremely fast response time.

- Interrogator detector requires extreme sensitivity, moderate damage threshold, extremely fast response time, and moderate linearity.

- Silicon PIN diodes are the preferred choice for cost, sensitivity and damage resistance.

- Signal detection at both vehicles rely on a narrow band pass optical filter for YAG wavelength to eliminate any noise bias.

- Signal processing at the target vehicle relies on a high band-pass electrical filter, along with level thresholding to drive a negative edge triggered device for high-noise immunity.

- Interrogator signal processing employs use of a hybrid detector/amplifier combination (1.2 GHZ) high band-pass electrical filtering, and ECL level comparators to make precise decisions on reflected intensities.

5.2.2 IFF CODING

The coding of the LRF with the IFF sequence is completely transparent to the gunner. The gunner sights on target, as usual, and fires the LRF while in IFF mode. A microcomputer intercepts the fire signal and begins a preselected pulse code sequence of the LRF unit.

The target vehicle contains a transceiver unit which contains a prior knowledge of the coded sequence and, upon receipt of the integrating pulses, it will reflect back its own coded return to the interrogator, identifying itself as a friend.

Since the pulse repetition rate of the M1 LRF cannot exceed 1/2 Hz for a maximum of four pulses, or .05 Hz for continuous pulse operation (per Hughes Manuf. LRF specification), the effective bandwidth cannot provide a robust coding. Therefore, a hybrid code format using pulse-width coding, combined with a digital coding has been devised.

In terms of simplicity, the retroreflector approach has strong merits. In this scenario, the interrogating vehicle first sends two pulses to the target (see Figure 5.3). The target will decode these pulses and compare it to the correct code. If the code is valid, the vehicle will anticipate two more pulses and respond by opening and closing a shuttered retroreflector in the correct reply sequence. The interrogator will then identify this sequence as high-intensity reflections different from a normal diffuse reflection. It will then look at the high versus the diffuse intensity as a binary 1 versus 0, and check for proper coding.

The first coding problem is to make the interrogation pulses unique to a preset code that the target vehicle will recognize as a valid and friendly interrogation. This is achieved by a precisely controlled time between LRF pulses. This time can be specified to within 500 microseconds, yielding a greatly increased effective code format of 1 in 1,000 possible codes (Figure 5.4).

The target vehicle can recognize a coded pulse sequence by the time between pulses (pulse delay). If the code is valid, the target vehicle will be synchronized in time with the interrogating vehicle. This synchronization accuracy corresponds to the speed of light and is well within the interrogator's .5 msec clock rate error.

Once the synchronization is established between the two vehicles, a pulse code can be retroreflected back by the target vehicle. The retroreflector produces an extremely high-intensity reflection in the same direction that the original pulse cam. By sampling the intensities of the returning LRF pulses, it is possible to distinguish between the target vehicle shutter being opened or closed. This closed or opened condition corresponds to the 0 and 1 bits, respectively, in a binary word (see Figure 5.5).

The complete interrogation and identification sequence is listed below and shown in Figures 5.3 and 5.4:

- All vehicles are preset with a mission code number.
- Interrogator vehicle sees a target and uses the LRF to prepare to fire.
- LRF emits two laser pulses that are precisely spaced according to the preset code (1 in 1,000 possible).
- LRF receives a target range, and this data is fed to

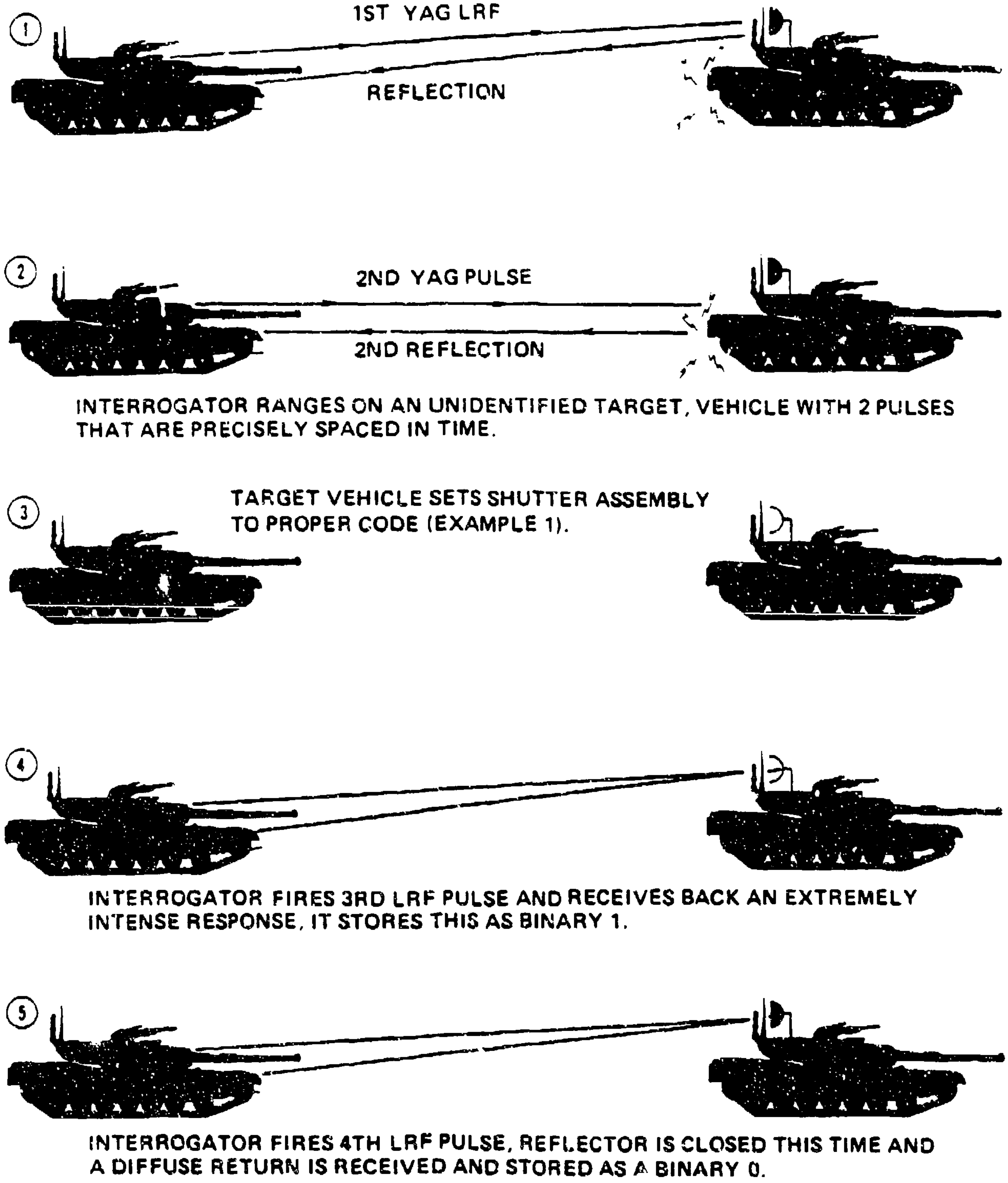


Fig. 5.3 CVIS Operation

the ballistic computer.

- Target vehicle receives the pulses and decodes the timing interval. The code is verified, synchronization is achieved, and operator is notified.

- The target vehicle retroreflects a binary two bit, code word 10,01, or 11, through a controllable shutter that covers the retroreflector (corner cube).

- Interrogator vehicle receives two intensity-coded pulses and compares them to the preset mission code and notifies the operator of friend or foe status.

Potential limitations of this approach are as follows:

- The timing diagram (Figure 5.5) shows that the identification process requires three seconds for completion.

- The LRF duty cycle specification (Hughes Mf) shows that the laser must wait for 20 seconds before it can initiate another interrogation.

- The target vehicle may have a 1 in 1,000 certainty that it is a friendly interrogation, but the interrogator only has a 1 in 3 certainty of a valid friendly reply.

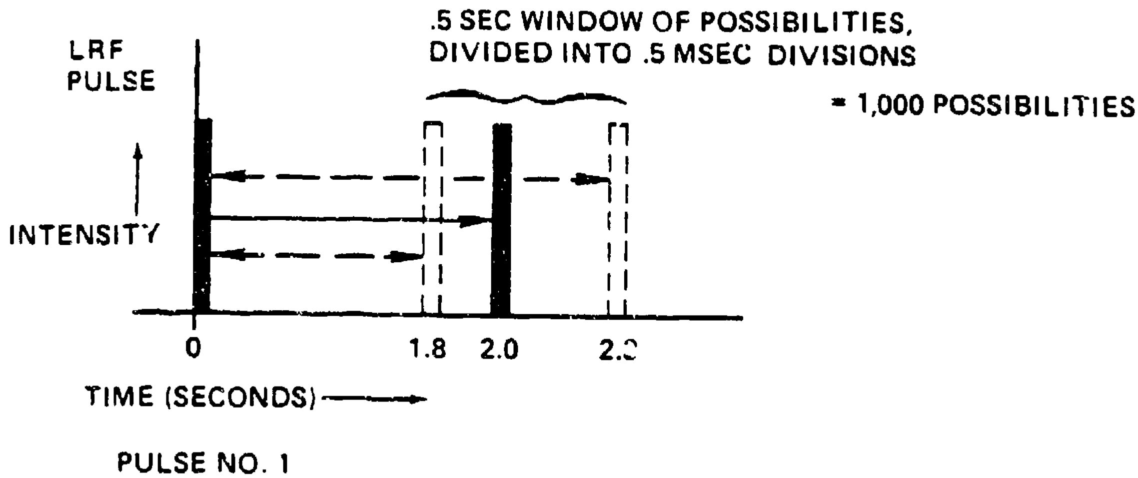


Fig. 5.4 Pulse Code Format

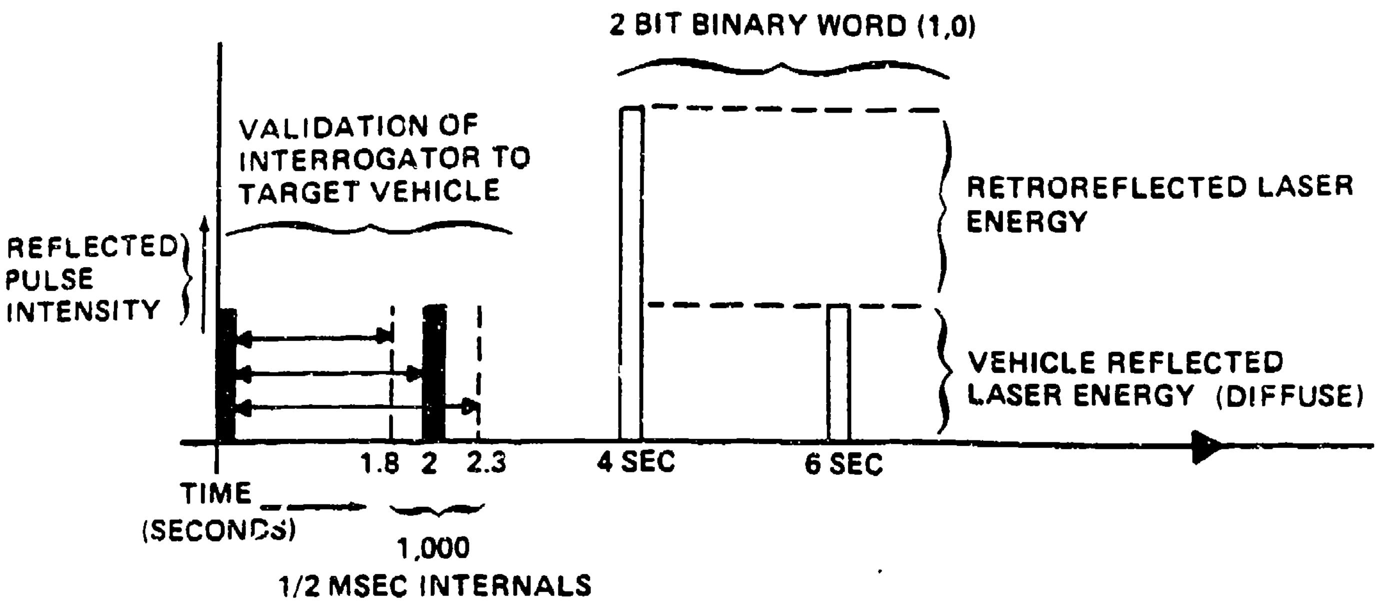


Fig. 5.5 CVIS Timing

It is important to note that this problem is associated with any design using the existing LRF for two reasons.

- The LRF laser is a passive (dye cell) Q-switched device with an 8 nanosecond pulse duration. This pulse is too fast to encode or chop information onto at the target vehicle.
- The maximum repetition rate is only once per two seconds. Up to a minimum of four pulses.

A comprehensive description of the M1 laser rangefinder may be found in the Appendix.

5.2.3 SOFTWARE DEVELOPMENT

In order to efficiently implement the code requirements detailed in section 5.22, "IFF coding" and maximize the system flexibility, a simple single chip microcomputer was utilized (Intel 8048). The system, as configured, allows for any future changes and improvements through software modifications without the need for hardware changes. This will allow implementation of any possible coding scheme in the field by merely changing the 8048, since it contains its own on-board software.

The software written to implement the CVIS functions is different for a target and a tank unit. It is important to note, however, that they both employ many identical subroutines, and both complete sets of software are loaded into each control unit. The choice of which software to run is set by a dip switch marked "Tank/Target", which is located on the controller circuit card next to the 8048 chip.

In an actual integrated production unit, the tank controller would choose which set of software to run, based on whether the gunner was interrogating a target, or whether the transceiver unit received an interrogating pulse from another "tank" vehicle.

The IFF function to be implemented in software would proceed as follows:

The interrogating vehicle first sends two pulses to the target. The target will decode the signal and compare it to the correct code. If the code is valid, the vehicle will anticipate two more pulses and respond by opening and closing a retroreflector in the correct reply sequence. The interrogator will then identify this sequency as high-intensity reflections different from a normal diffuse reflection. It will then look at the high versus the diffuse intensity as a binary 1 versus 0, and check for proper coding.

The first two laser pulses (tank), spaced in time by the preset code, are received and decoded by the target vehicle, as shown in Figures 5.3 & 5.6. The timing intervals are then synchronized so that the target vehicle can retroreflect the next two tank pulses in a binary code, also determined by the preset code.

TIMING DIAGRAM

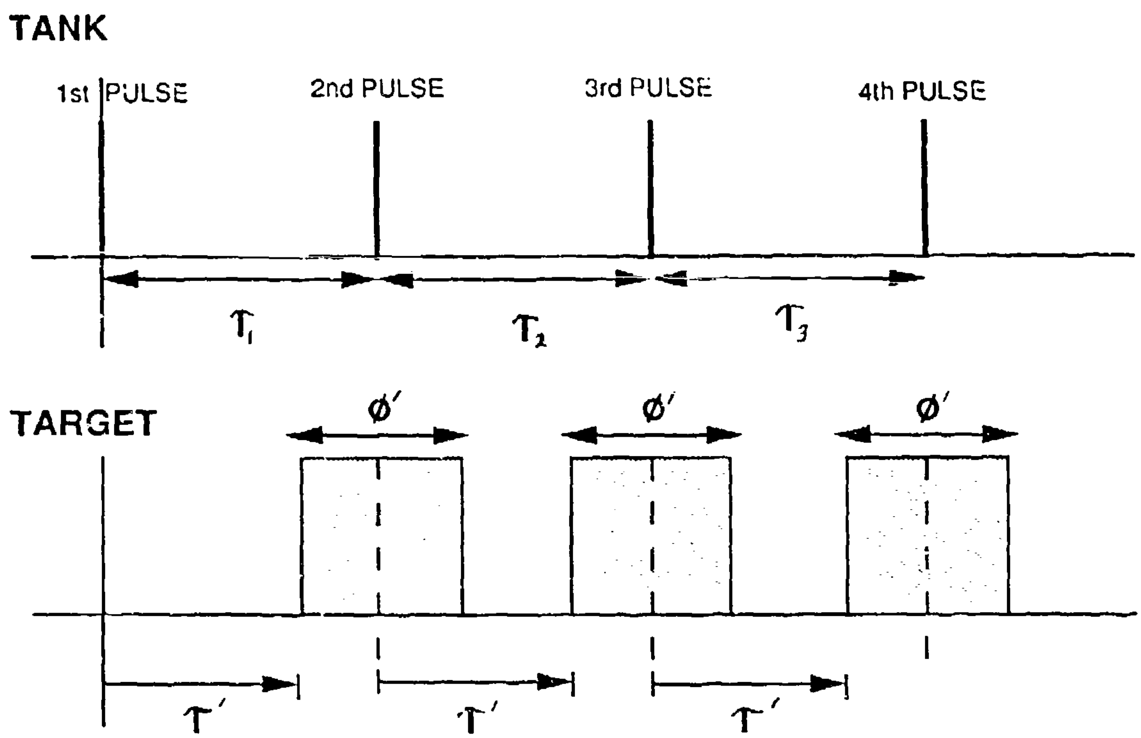


Fig. 5.6 Tank/Target Time Sequence

The first three digits of the timing code determine the space between pulses T_1, T_2, T_3, respectively as shown in Figures 5.6 & 5.7. Each displayed unit T is approximately one quarter of a second delay (i.e., T value of 4 equivalent to 4x.25=1 second). The fourth digit determines the time length 0 of the receiving window (the second pulse) and the shutter window of the retroreflector (the third and fourth pulse).

EXAMPLE CODE **4 2 4 3**

Fig. 5.7 Code Example

In the following figures, Figure 5.8 is a software overview in flowchart form showing the entire IFF sequence for the Interrogation and the target units.

Figures 5.9 & 5.10 break the software down further into flow charts depicting the relationships of the actual subroutings and their corresponding timing offset values added to the IFF sequence. These subroutines are then defined in Figure 5.11 to clarify the functionality of the subroutine relationships.

The calculation of the time constants and timing loop values are shown in Figure 5.2 for the tank software in fire mode, and in Figure 5.13 for the tank (interrogator software) in receive mode, which is the same subroutine as the target software in transceive mode.

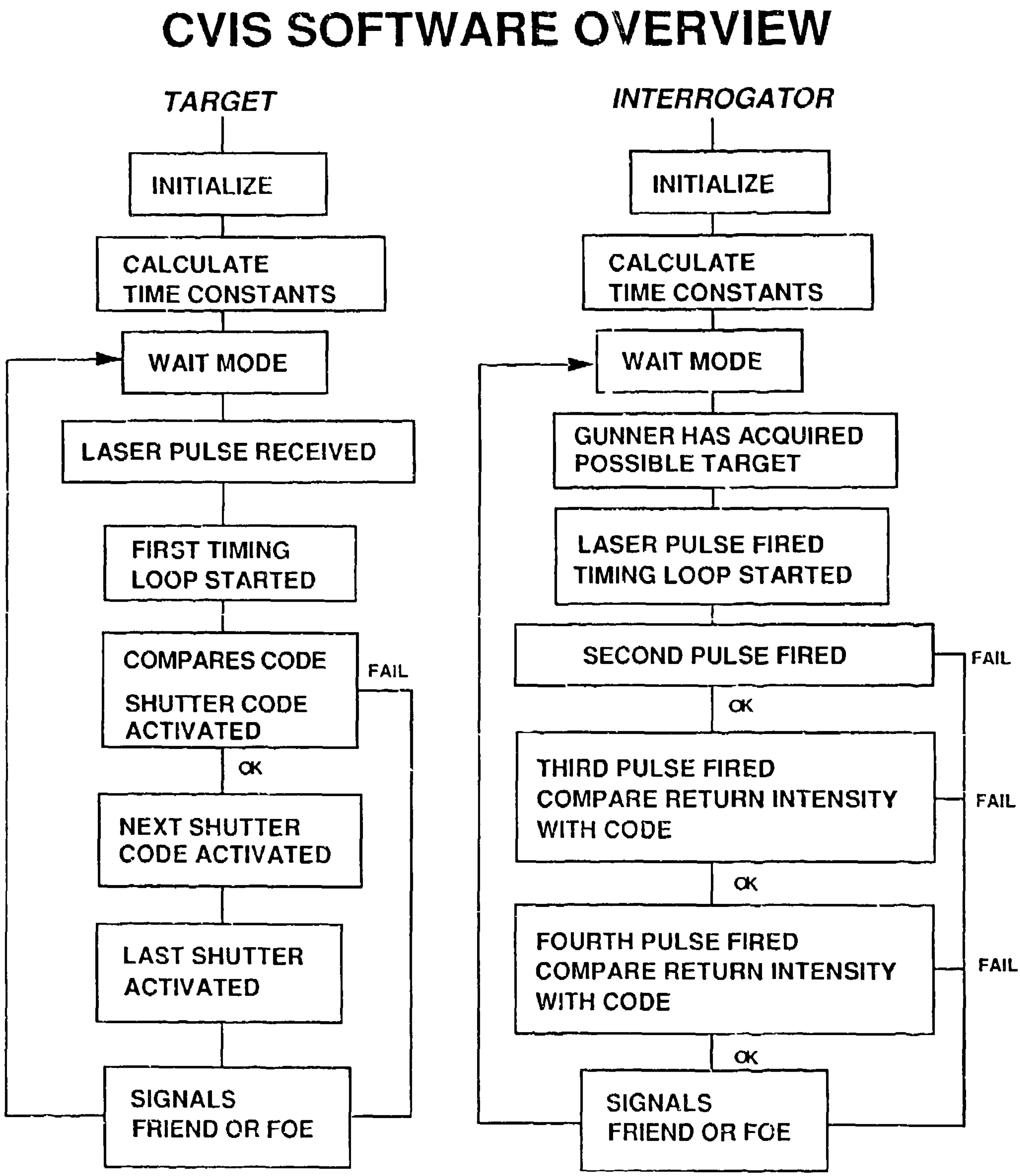


Fig. 5.8 Software Overview

TANK SOFTWARE TIMING FOR CVIS

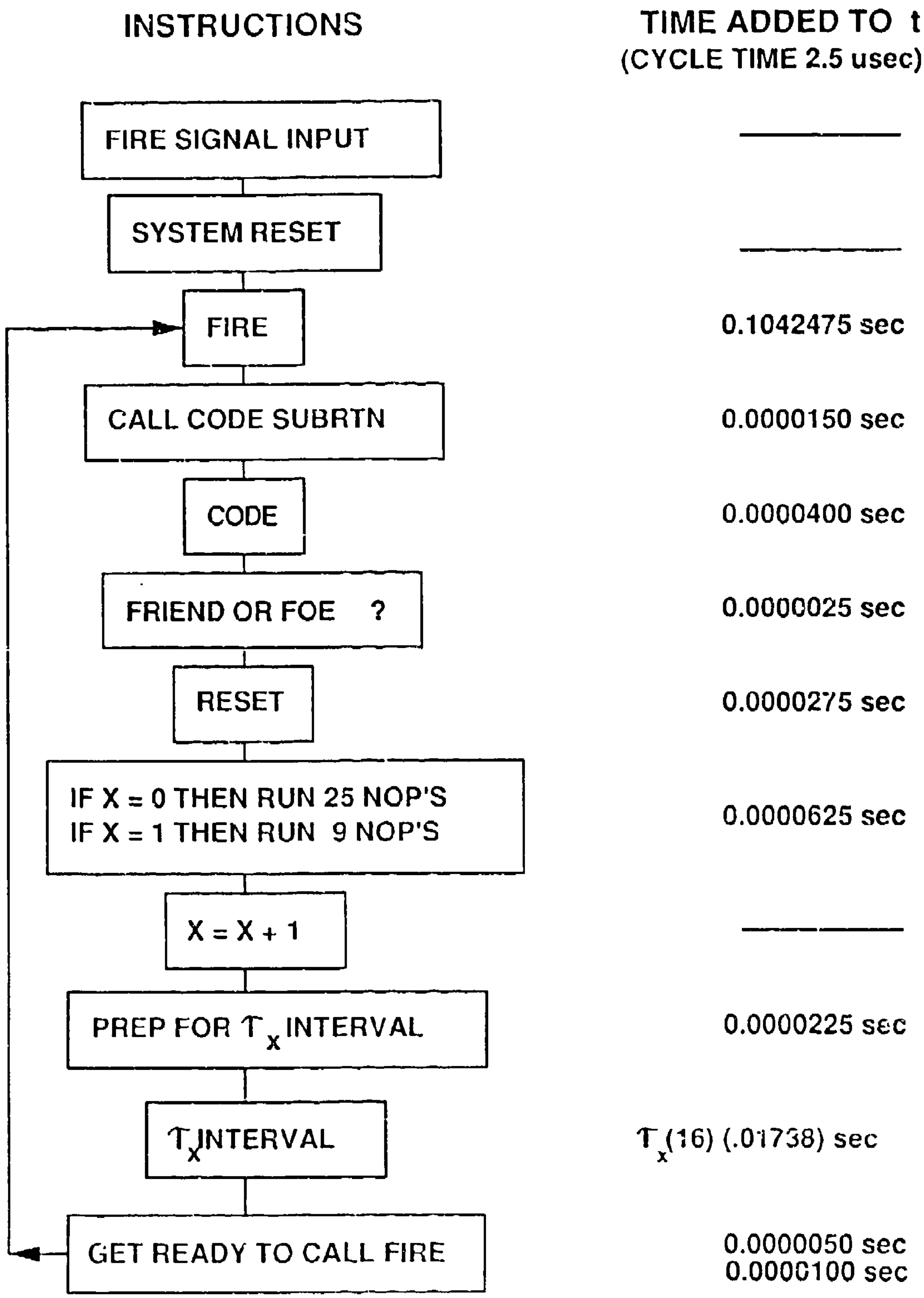


Fig. 5.9 Tank Software Timing

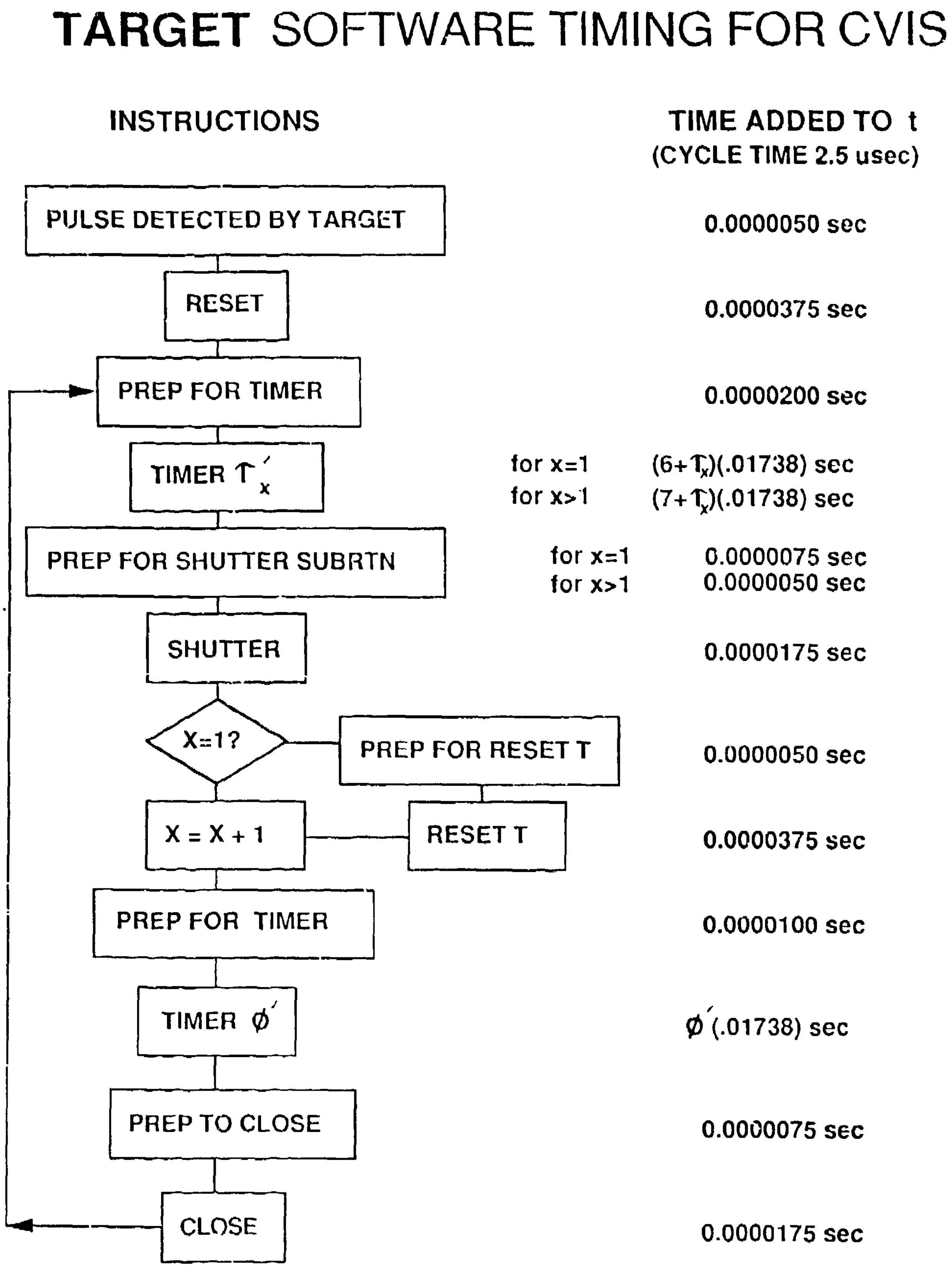


Fig. 5.10 Target Software Timing

TANK SOFTWARE INSTRUCTIONS

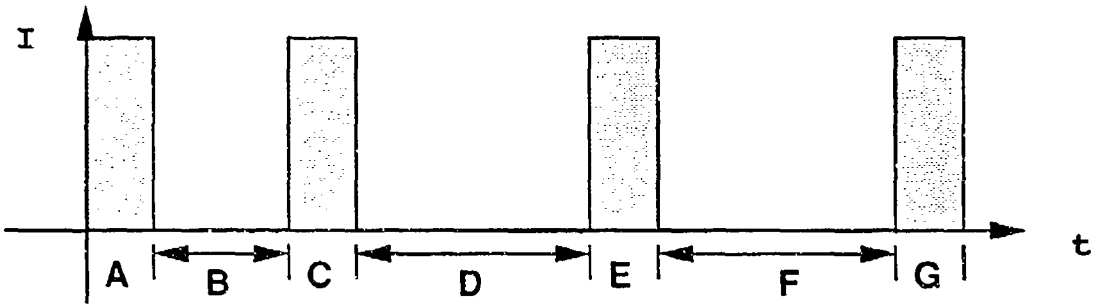
SYSTEM RESET	RESETS ALL VARIABLES TO DEFAULT CONDITIONS
CODE/CODE SUBRTN	COMPARES RETURN PULSE WITH SHUTTER CODE
FRIEND OR FOE?	DETERMINES IF PULSE IS OF PROPER INTENSITY
RESET	RESETS ALL FLIP-FLOPS TO AVOID LASER PULSE
τ_X INTERVAL	TIME DELAY BETWEEN LASER PULSES
CALL FIRE	DECREMENTS LASER PULSE COUNTER RESETS FOR NEXT PULSE SETS TIME DELAY

TARGET SOFTWARE INSTRUCTIONS

RESET	RESETS ALL FLIP-FLOPS TO AVOID LASER PULSE
TIMER τ'_X	TIME DELAY BETWEEN FALLING EDGE OF LASER PULSE AND RISING EDGE OF RECEIVING WINDOW
SHUTTER	RESETS LASER SIGNAL FLIP-FLOPS
RESET T	SETS SHUTTER CODING -OPEN/CLOSE
TIMER ϕ'	OPENS WINDOW TO RECEIVE LASER PULSE
CLOSE	CLOSES THE SHUTTER

Fig. 5.11 Software Instructions / Subroutines

TANK SOFTWARE TIMING DIAGRAM
FIRING SEQUENCE



A = 0.1042475 sec

B = 0.0001225 + T_1 (0.27804) sec

C = 0.1042475 sec

D = 0.0174650 + T_2 (0.27804) sec

E = 0.1042475 sec

F = 0.0174650 + T_3 (0.27804) sec

G = 0.1042475 sec

TARGET SIGNAL RETURN

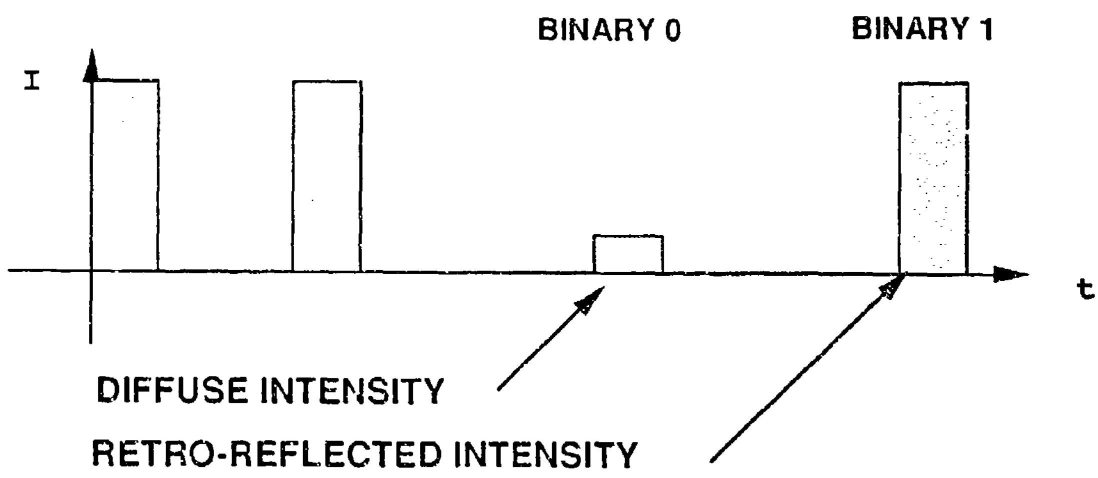
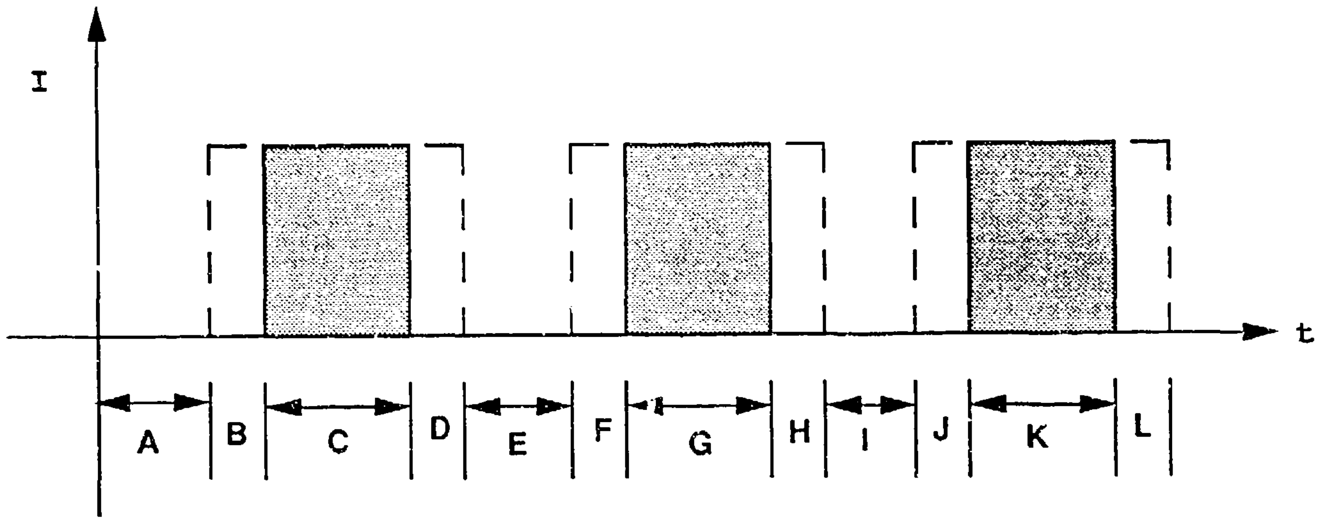


Fig. 5.12 LRF Software Firing Sequence

RECEIVING WINDOW TIMING DIAGRAM



RECEIVING WINDOW

WINDOW OFFSET

$A = 0.10436625 + (T_1 - \phi/2)(0.27804)$ sec

$B = 0.00006125$ sec

$C = \phi(0.27804)$ sec

$D = 0.00001625$ sec

$E = 0.12170375 + (T_2 - \phi)(0.027804)$ sec

$F = 0.00003500$ sec

$G = \phi(0.27804)$ sec

$H = 0.00001375$ sec

$I = 0.121702 + (T_3 - \phi)(0.27804)$ sec

$J = 0.00002375$ sec

$K = \phi(0.27804)$ sec

$L = 0.00001375$ sec

$T_1' = 16T_1 - 8\phi$

$T_2' = 16T_2 - 16\phi$

$T_3' = 16T_3 - 16\phi$

$\phi' = 16\phi$

Fig. 5.13 Receiving Window Timing

5.2.4 FABRICATION/INTEGRATION

To ensure proper operation and minimize chances for electrical and machanical failures and interferances (EMI/EMC), a number of precautions have been taken in the design and fabrication of the CVIS system. These precautions have paid off in the field testing since no compatibility problems were encountered when the CVIS system was installed on an M1A1.

ELECTRICAL INTERFACE

All signals transmitted over the cables are driven by differential line drivers and received by differential line receivers. Each differential pair is a twisted shielded pair to eliminate crosstalk and false signalling. The cables are R.F shielded with their grounds to chassis (battery case and controller cases) and do not share an analog signal ground, or a digital ground.

In addition, all signal grounds are single point with their origin in the main battery box, to minimize or eliminate any ground looping.

The components selected all have extended mil-spec temperature capabilities, as well as the microprocessor having 168 hours of burn-in.

MECHANICAL

- All external boxes are designed to be weatherproof with welded seams and full gasket sets on covers lenses, connectors, filter, and bolts. Construction is 6061-T6 aluminum typically .375 inch thickness for maximum strength and weight savings.
- Magnetic bases rejected due to poor surface quality. Strapdowns and clamps are designed to secure all boxes.
- Control boxes (internal) will only be weather resistant to the extent of the switches and indicator interfaces.

5.3 TESTING

SUMMARY

Overall, the CVIS hardware performed well in the field with successful operation under all requirements of the feasibility test. The hardware being at a brassboard stage did require calibration during setup but exhibited no problems which would inhibit and optimize system from being fully integrated into the tank.

Testing of the CVIS hardware was conducted in three phases. The first phase was a basic system checkout conducted at TACOM over a 200 meter test range. The second stage of testing was performed at the CECOM/Wayside, N.J., laser test range near Ft. Monmoth, N.J. This test was a stand alone system test to address maximum range requirements. The final system test was conducted at Ft. Knox and included systems operation with the CVIS system installed on a M1A1.

The purpose of the three phases of testing was to determine possible design problem before the next stage of testing complexity (for a full description of the test plans, see APPENDIX A). The functional performance criteria were designed as follows:

	Function	Test Site
a)	Operation of proper IFF code	All
b)	Rejection of improper codes	All
c)	Max operating range	Wayside, N.J. (test #2)
d)	Min operating range	TACOM (test #1)
e)	Operation in sunlight & darkness	TACOM & Wayside
f)	Operation in foliate cover	Wayside, N.J.
g)	Minimum integration time	TACOM & Wayside
h)	Reliability at range	Wayside & Ft. Knox
i)	Ability to spoof or jam system	Wayside, N.J.

There have been no subsystem-level testing conducted, since the seperate components were tested at the time of assembly.

Equipment Under Test. The equipment consists of two main systems, a tank system and a target system, as shown in Figure 5.14. The tank system is the Laser/Interrogator and consists of a control unit, a receiver unit, a power supply, and an interface to a laser rangefinder test firing box or M1 GPS. The control unit, as shown in Figure 5.15, houses a microprocessor and includes a shutter code selector, a time code selector, and friend or foe warning indicators. Contained in the receiver unit as shown in Figure 5.16, is a high-speed Nd:YAG detector and signal conditioning electronics. The power supply houses two 12-volt batteries which provide power to the system (visible on ground in Figure 5.17). The target system is the Receiver/Transponder and consists of a control unit, a transceiver unit, and a power supply. Both the control unit and the power supply are identical to those of the tank system. The transceiver unit (shown in Figures 5.17 & 5.18) contains a multiple high-speed Nd:YAG detector system, a high-speed electronic shutter, a retroreflector and supporting electronics.

CVIS SYSTEM LAYOUT

Tank System

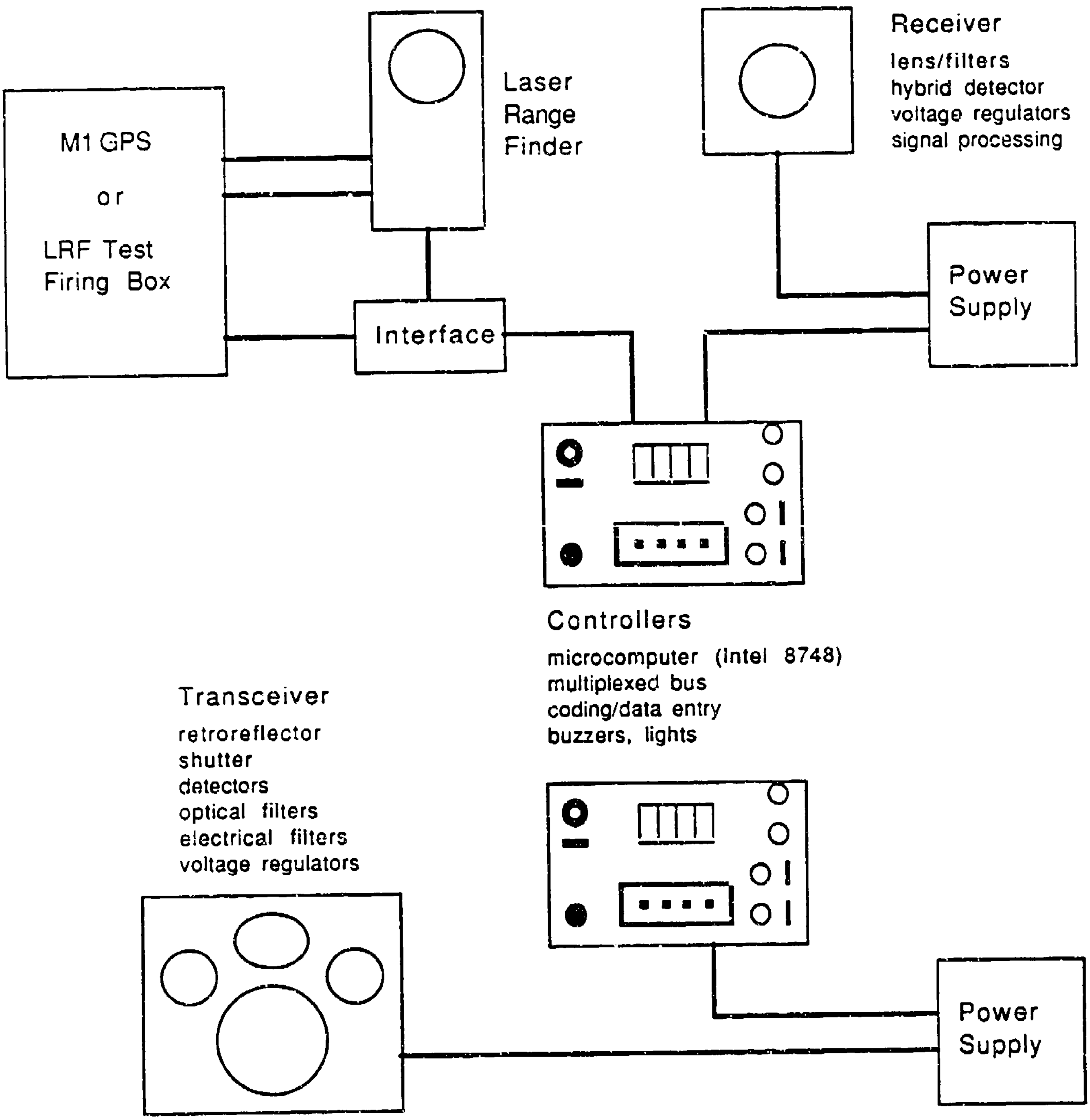


Fig. 5.14 CVIS System Layout

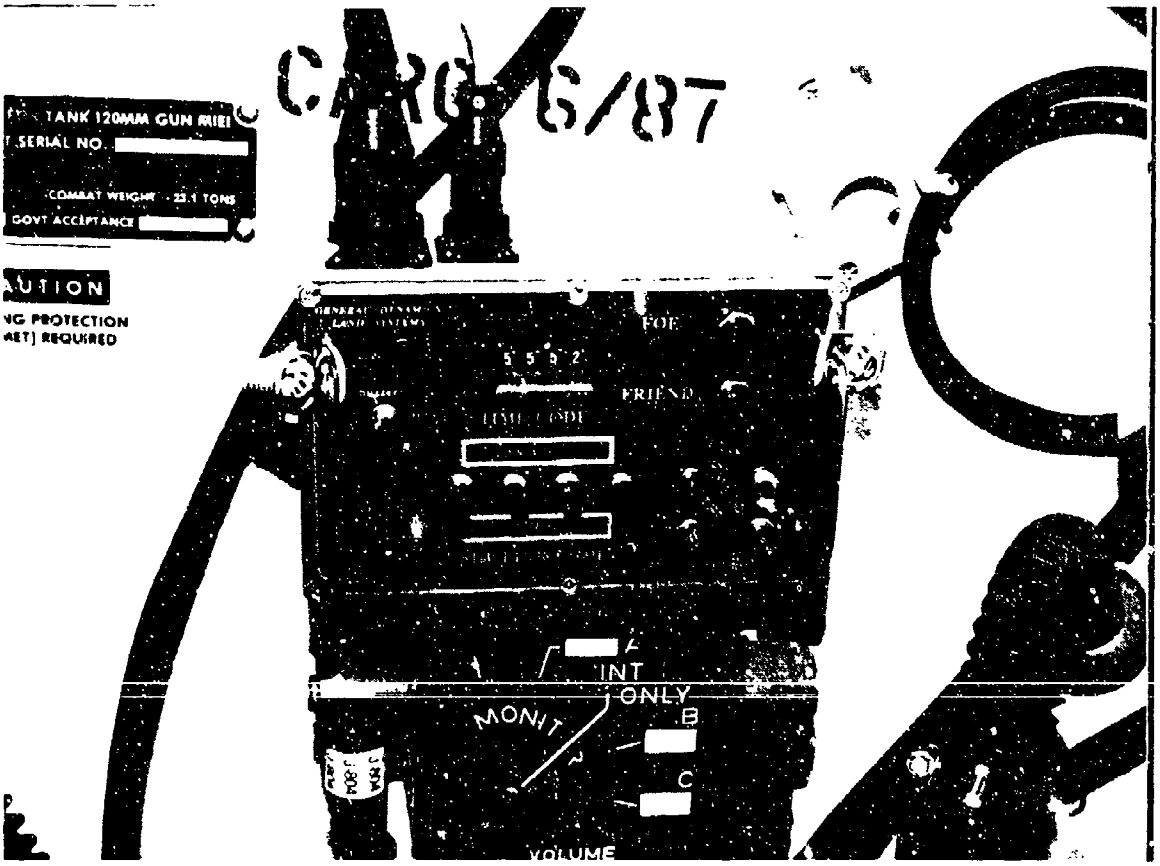


Fig. 5.15 CVIS Control Unit

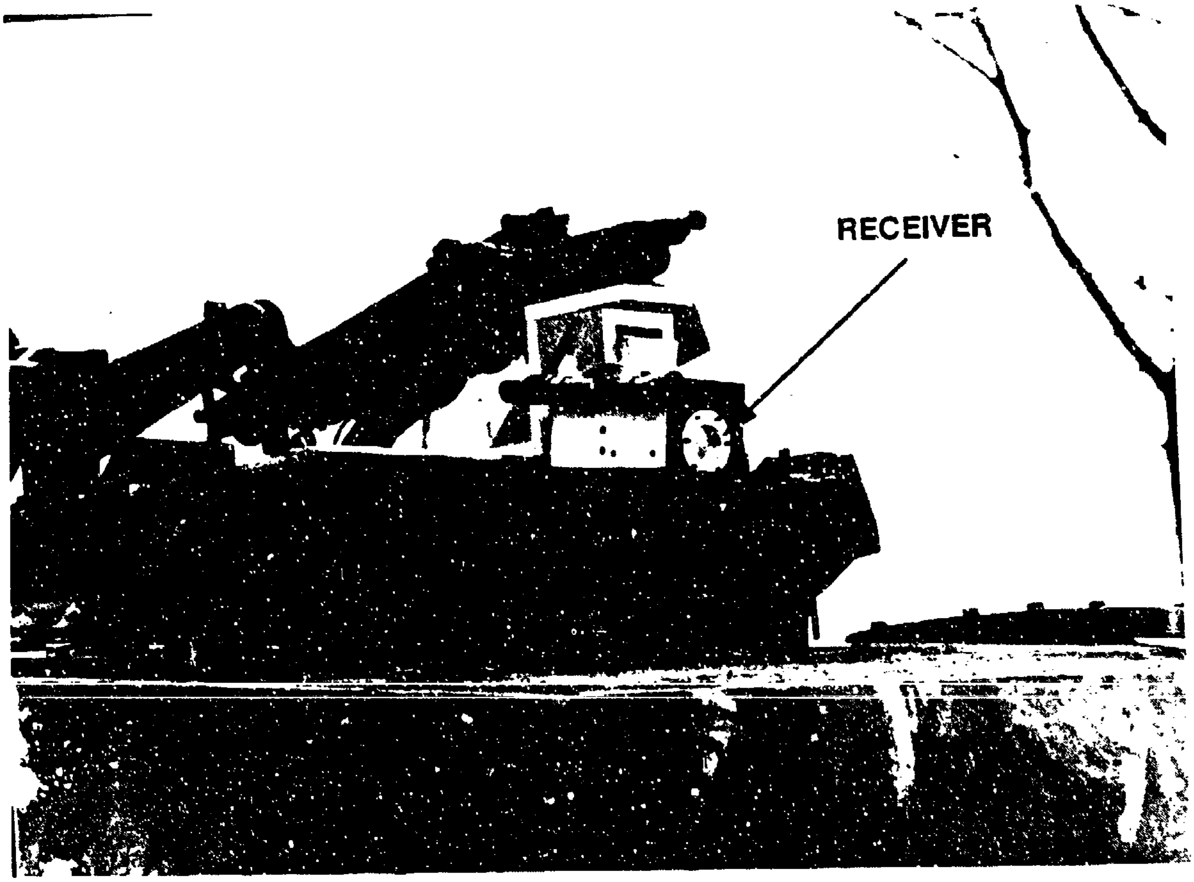


Fig. 5.16 CVIS Tank Unit Receiver

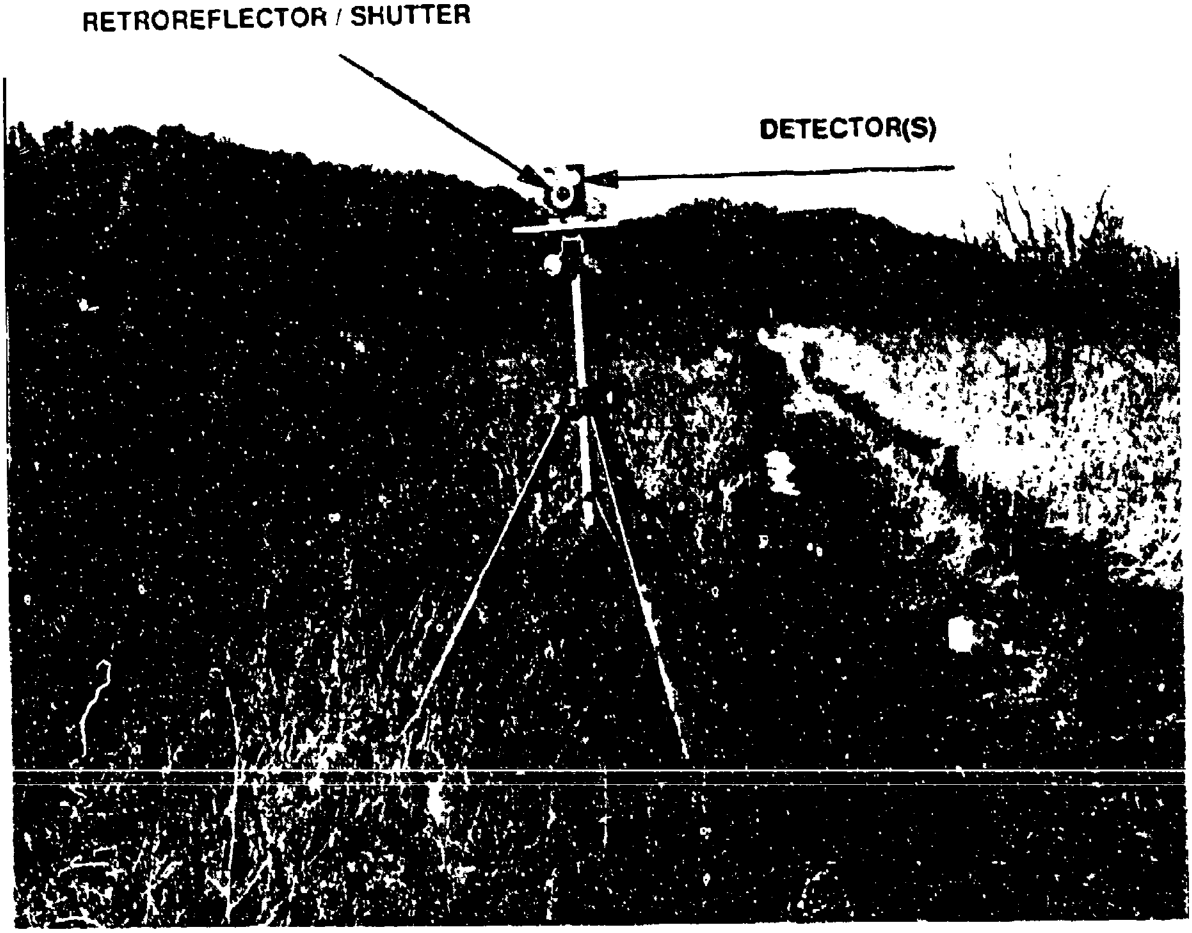


Fig. 5.17 CVIS Transceiver Unit

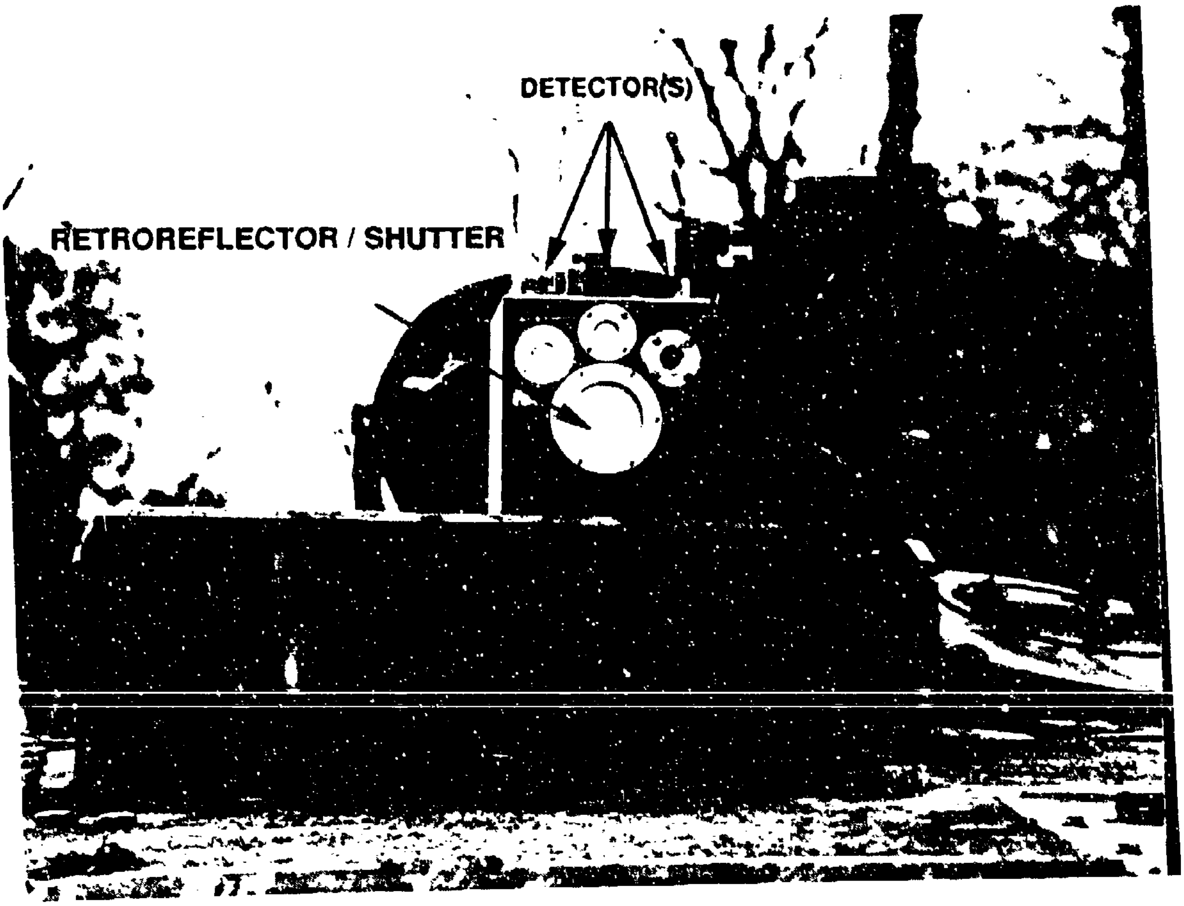


Fig. 5.18 CVIS Transceiver Unit

TACOM TEST

The purpose of the TACOM test was to establish basic functionality of the CVIS system in the field. In addition, the testing objective was to determine minimun operational distance, minimum interrogation time and total angular coverage. The TACOM test was successfully completed for two of the three planned tests. The minimum interrogation time test could not be completed because of a faulty battery pack. The faulty unit could not be isolated at the time of testing because of nightfall.

The results are as follows:

TEST SUMMARY

Min Range	<200 meters
Field of View	≥65

FUNCTIONALITY TEST

The first five laser pulses in the functionality test (Table 5.1) were to calibrate the detectors and properly align the system. The next five interrogations were successful. Since testing was completed at a range of less than 200 yards, the CVIS system exceeded the capability of LRF min range requirement of 200 yards.

TABLE 5.1

FUNCTIONALITY TEST. TIME: 6:55pm

	LASER/INTERROGATOR			RECEIVER/TRANSCEIVER		
Test No.	Shutter Code	Time Code	Friend/ Foe	Shutter Code	Time Code	Friend/ Foe
1 CAL.	0010	7773	Friend/	0010	7773	Friend
2 CAL.	0010	7773	Foe	0010	7773	Foe
3 CAL.	0011	7773	Foe	0011	7773	Foe
4	0011	7773	Friend	0011	7773	Friend
5	0011	7773	Friend	0011	7773	Friend
6	0001	7773	Friend	0001	7773	Friend
				0010	7773	Foe
Notes:						
7	0010	7773	Friend	0010	7773	Friend
A1	0001	7773	Friend	0001	7773	Friend
A2	0010	7773	Friend	0010	7773	Friend
A3	0011	7773	Friend	0010	7773	Friend

ANGULAR FIELD OF VIEW

The angular field was established to be 35 counterclockwise (top down) and 30 in the clockwise direction. Thus, the total angular field of view was established to be 65 (Table 52.2).

ANGULAR FIELD-OF-VIEW TIME: 7:30pm

TABLE 5.2

LASER/INTERROGATOR					RECEIVER/TRANSCEIVER		
Test No.	Rec. Angle	Shutter Code	Time Code	Friend/ Foe	Shutter Code	Time Code	Friend/ Foe
1	10	0011	7773	Friend	0011	7773	Friend
2	20	0011	7773	Friend	0011	7773	Friend
3	30	0011	7773	Friend	0011	7773	Friend
4	30	0011	7773	Friend	0011	7773	Friend
5	30	0011	7773	Friend	0011	7773	Friend
6	35	0011	7773	Friend	0011	7773	Friend
7	35	0011	7773	Friend	0011	7773	Friend
8	30	0011	7773	Friend	0011	7773	Friend
9	25	0011	7773	Friend	0011	7773	Friend
10	30	0011	7773	Friend	0011	7773	Friend
11	30	0011	7773	Friend	0011	7773	Friend
12	30	0011	7773	Friend	0011	7773	Friend

Maximum angle of operation __65__.

MINIMUM INTERROGATION TIME

Test was postponed at Wayside, N.J., due to a faulty battery pack which was not diagnosed on the TACOM range because of nightfall.

Wayside N.J. Test

The testing scheduled for the White Sands Missle Range was rescheduled, per TACOM direction, to the Wayside, N.J. site.

The purpose of this test was to conduct maximum range testing, operate in sunlight and darkness resistance to "spoof" attempts, foliate cover, and minimum interrogation time.

Overall the system performed very well in this test. The system continued to operate at 3.0 km, which was the maximum range of the test field. It was also unaffected by conditions of sunlight or darkness, and failed to be "spoofed" by aluminum foil and cornercubes. Minimum interrogation time was determined to be 3 seconds or less.

WAYSIDE, N.J. TEST SUMMARY

Operational Range	3 km ++
Spoof Test	Pass
Min Interrogation Time	3 seconds
Operation Sunlight/Darkness	Pass

The minimum interrogation time test (Table 5.3) was conducted under conditions of generally "good" visibility at a range of 1.8 kilometers. The two highlighted data sections indicate consistently proper operation with a code setting of 4443, which translates into an interrogation time of three seconds (see Section 5.2.2 - 5.2.3 for calculations). It should be noted that operation was conducted at 3332 (interrogation time = 2.25 sec.), but the results were inconsistent and thus not claimed as a true minimum interrogation time. Therefore, any previous testing conducted at 3332 will be disregarded.

Minimum Interrogation Time Date: 30 September 1988

TABLE 5.3

	LASER/INTERROGATOR			RECEIVER/TRANSCEIVER				
Test No.	Oper. Distance	Shutter Code	Time Code	Friend/ Foe Code	Shutter Code	Time Code	Friend Foe	Time Test
CAL 1	1.8km	0011	4442	foe	0011	4442	friend	1435
CAL 2	1.8km	0011	4442	foe	0011	4442	friend	
CAL 3	1.8km	0011	4443	friend	0011	4443	friend	1440
3.1	1.8km	0011	4443	foe	0001	4443	foe	
3.2	1.8KM	0011	4443	friend	0001	4443	friend	1443
3.3	1.8km	0010	4443	friend	0010	4443	friend	
3.4	1.8km	0010	3332	friend	0010	3332	friend	
3.5	1.8km	0001	3332	foe	0001	3332	friend	1452
3.6	1.8km	0001	3333	foe	0001	3333	friend	
3.7	1.8km	0001	3331	foe	0001	3331	friend	
3.8	1.8km	0001	3332	foe	0001	3332	friend	
3.9	1.8km	0011	3332	foe	0011	3332	friend	1504
4	1.8km	0011	4443	friend	0011	4443	friend	
4.1	1.8km	0010	4443	friend	0010	4443	friend	1508
4.2	1.8km	0001	4443	friend	0001	4443	friend	1510

The test for maximum operational distance (Table 5.4) was conducted under good visibility. The first three tests were to recalibrate the system after moving it from the 2.5 km range point.

The first three actual tests (T10-T12) represent successful operation at the 3 kilometer range. The remainder of the test was dedicated to determining minimum interrogation time, which is a separate test conducted at a range of 1.8 kilometers.

The data supports the results of the actual minimum interrogation time test, in that sporadic operation began after the minimum code 444X was successfully implemented. Thus, the 333X codes will not be considered in the overall probability calculations, since they are outside of the stated system specifications, and the purpose of the test was to determine the cutoff between maximum speed and system errors.

It should also be noted that tests T-28 and T-29 were conducted with a change in detector thresholding. This was done in an attempt to reinstate operation, since it was not determined, at the time, that 3332 was a code outside of the speed capabilities of the system (actually the LRF was the limiting factor, as it would not fire consistently at this rate).

TABLE 5.4

Maximum Operational Distance   Date: 30 September 1988

		LASER/INTERROGATOR			RECEIVER/TRANSCEIVER			
Test No.	Oper. Distance	Shutter Code	Time Code	Friend/ Foe	Shutter Code	Time Code	Friend/ Foe	Time Test
C.1.B	3km	1111	9994	friend	0000	9994	foe	1200
C.2.B	3km	1111	9994	foe	0000	9994	foe	1220
C.3.B	3km	1111	9994	friend	1111	9994	friend	1220
T10	3km	0001	9994	friend	0001	9994	friend	1225
T11	3km	0010	9994	friend	0010	9994	friend	1230
T12	3km	0011	9994	friend	0011	9994	friend	1233
T13	3km	0110	7773	friend	0110	7773	friend	1235
T14	3km	0010	5553	friend	0010	5553	friend	1240
T15	3km	0010	5552	no reading	0010	5552	foe	1243
T16	3km	0010	5552	friend	0010	5552	friend	
T17	3km	0010	4442	friend	0010	4442	friend	
T18	3km	0010	3332	foe	0010	3332	friend	1250
T19	3km	1010	3332	foe	1010	3332	foe	1300
T20	3km	1010	3332	foe	1010	3332	friend	
CAL 1	3km	1010	3332	foe	1010	3332	foe	1307
CAL 2	3km	1010	3332	friend	1010	3332	friend	
CAL 3	3km	0010	3332	friend	0010	3332	friend	
T21	3km	0010	3332	friend	0010	3332	friend	1313
T22	3km	0001	3332	foe	0001	3332	foe	
T23	3km	0001	3332	foe	0001	3332	friend/foe	
T24	3km	0001	3332	friend	0001	3332	friend	1350
T26	3km	0011	3332	foe	0011	3332	foe	
T27	3km	0011	3332	foe	0011	3332	friend	1354
T28	3km	0011	4442	foe	0011	4442	foe	
T29	3km	0011	4442	foe	0011	4442	foe	

Test T15. This was a nontest. Accidental laser firing.
Test T21 - Minimum operational time.

"SPOOF" TEST

The spoof test (Table 5.5) was also conducted as part of the maximum range test at 2.5 kilometers. The spoof tests were made after the system was determined to be operating properly at 2.5 km. Two tests were conducted. The first (S1) involved hanging a reflective sheet of aluminum foil (1 ft x 3 ft) behind the target transceiver unit. The second test (S2) added a corner cube type reflector (3" x 3" x 3") to the foil background.

The CVIS unit was unaffected by either of these additions and continued to function normally.

TABLE 5.5

		LASER/INTERROGATOR			RECEIVER/TRANSCEIVER	Time: 1700	
Test No.	Oper. Distance	Shutter Code	Time Code	Friend/ Foe	Shutter Code	Time Code	Friend/ Foe
S1	2.5km	0010	8883	friend	0010	8883	friend
S2	2.5km	0010	8883	friend	0010	8883	friend

FOLIATE COVER TEST

The Foliate Cover Test (Table 5.6) was conducted under good visibility at a range of 2.5 km. Implementation was achieved by suspending tree branches, with their leaves intact, aprroximately midway between the test units. Operation of the CVIS unit was successful to the extent that the LRF could functionally punch through foliage and still get an accurate range (tests SF1 and SF2). In tests SF3 and SF4, the LRF was unable to get an accurate range of the target transceiver.

TABLE 5.6

FOLIATE COVER TEST Time: 1750 29 September 1988

		LASER/INTERROGATOR			RECEIVER/TRANSCEIVER		
Test No.	Oper. Distance	Shutter Code	Time Code	Friend/ Foe	Shutter Code	Time Code	Friend/ Foe
SF1	2.5km	0010	8883	foe	0010	8883	foe
SF2	2.5km	0010	8883	foe	0010	8883	foe
SF3	2.5km	0010	9994	friend	0010	9994	friend
SF4	2.5km	0010	9994	friend	0010	9994	friend

The foliage was positioned approximately 1815 meters away from the Receiver/Transceiver. The aluminum foil from the "spoof" attempt was still in place.

DARKNESS TEST

The Darkness Test (Table 5.7) was conducted under conditions of fog, dew, and complete darkness. The dew proved the only significant problem as it clouded up the transmitter and receiver optics.

The first three calibration tests represent adjustments to the detector to minimize the effects of the backscatter from the fog, which was significant for a 3 km range. The fourth cal test (C4) was the only check needed to facilitate operation at 1.5 kms.

The remainder of the testing was successful at the 1.5 km range with a code of 9994. Test T6 was ommitted due to a breakdown in communication on the test range and was not observed by the downrange observer.

TABLE 5.7

DARKNESS TEST Time: 2010 Date: 29 September 1988

		LASER/INTERROGATOR			RECEIVER/TRANSCEIVER		
Test No.	Oper. Distance	Shutter Code	Time Code	Friend/ Foe	Shutter Code	Time Code	Friend/ Foe
C1	3km	0010	9994	foe	0010	9994	foe
C2	3km	0010	9994	foe	0010	9994	foe
C3	3km	0010	9994	friend	0010	9994	no reading
C4	1.5km	0010	9994	foe	0010	9994	foe
T4	1.5km	0010	9994	friend	0010	9994	friend
T7	1.5km	0001	9994	friend	0001	9994	friend
T8	1.5km	0011	9994	friend	0011	9994	friend

FT. KNOX TEST

The test at Ft. Knox was intended to provide data relating to the installation of the CVIS system on an M1 in the field. The scope of the original test included firing the laser at a vehicle downrange. This was not possible due to range safety regulations. It is believed that the lack of a target with sufficient cross-section caused the error introduced in this test.

The CVIS system was completely installed and functional within one hour, well within the requirements (three hrs) shown in Figures 5.19, 5.20, 5.21 & 5.16. In Figure 5.19,

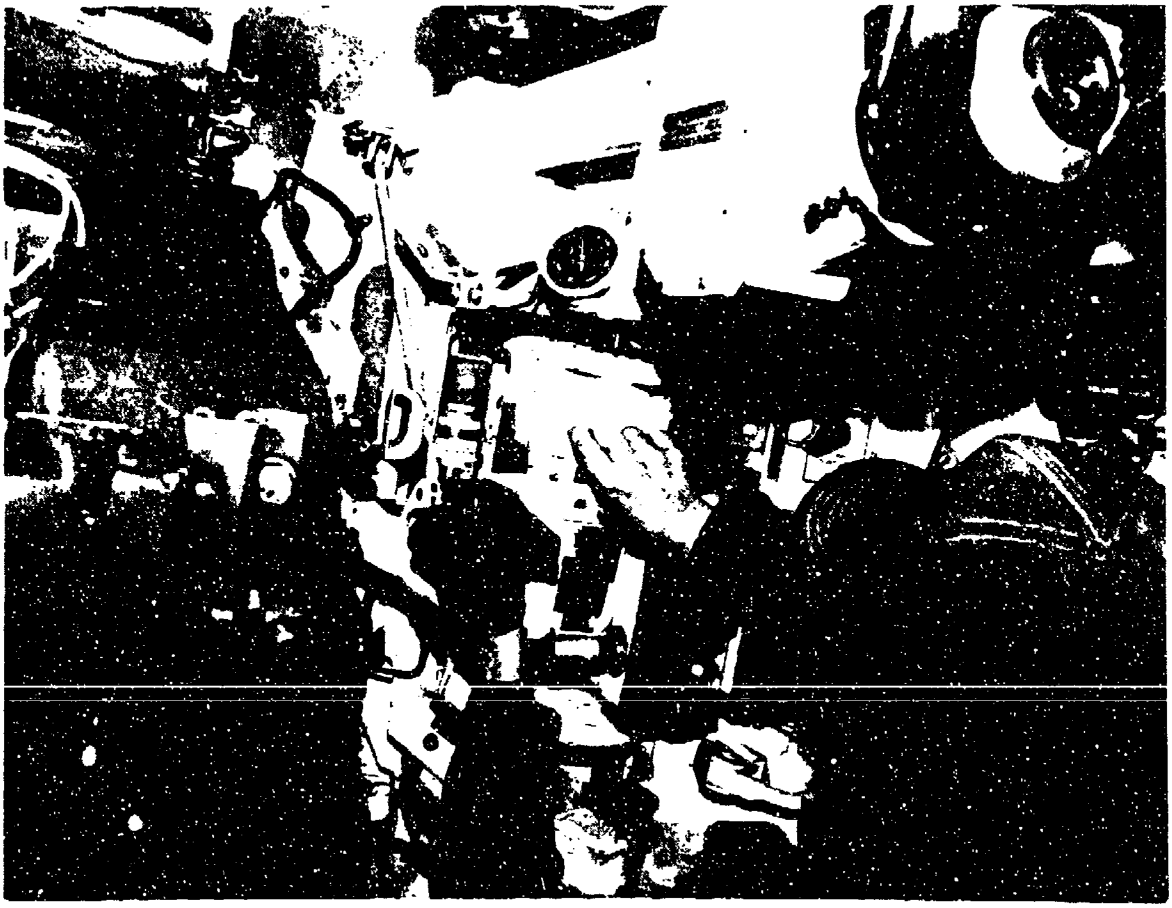


Fig. 5.19 CVIS Installation 1

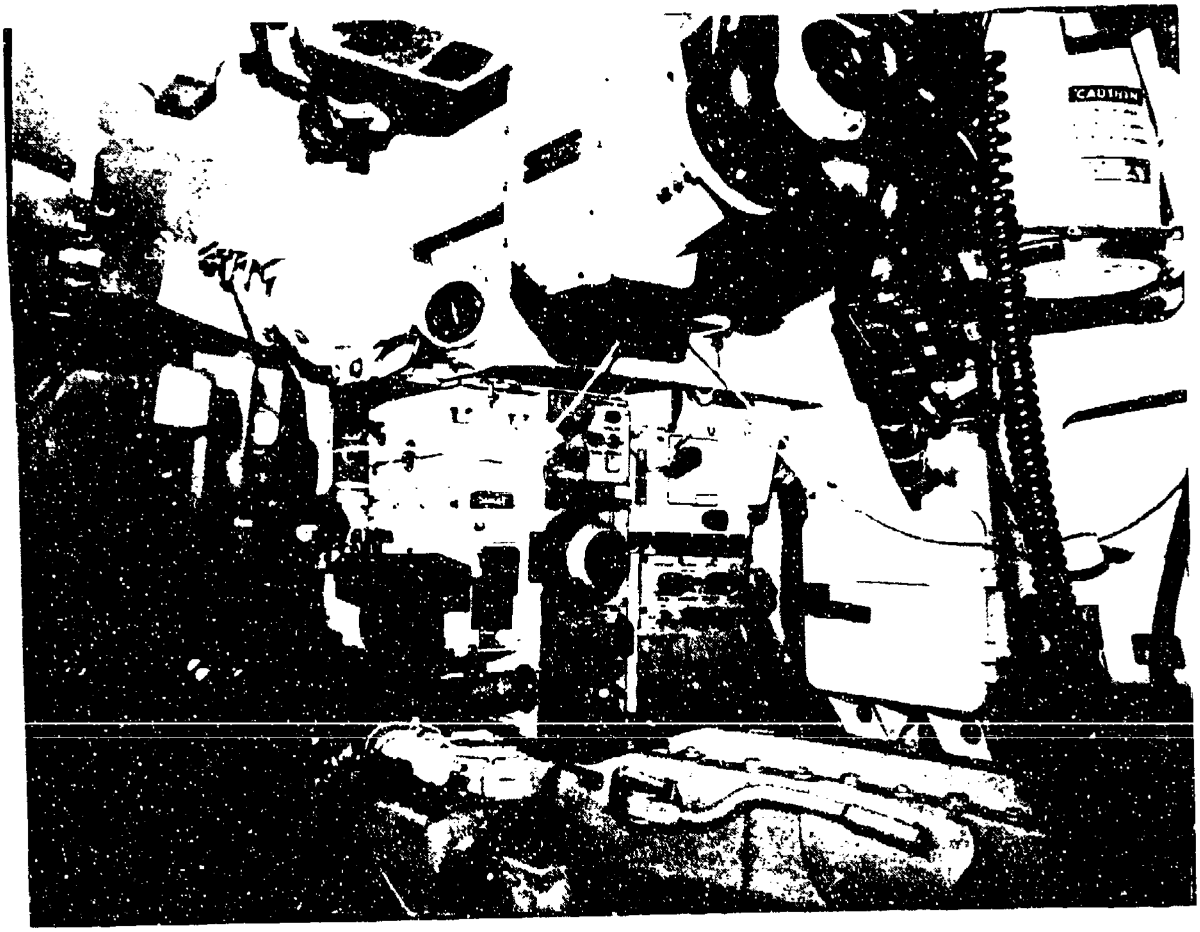


Fig. 5.20 CViS Installation 2

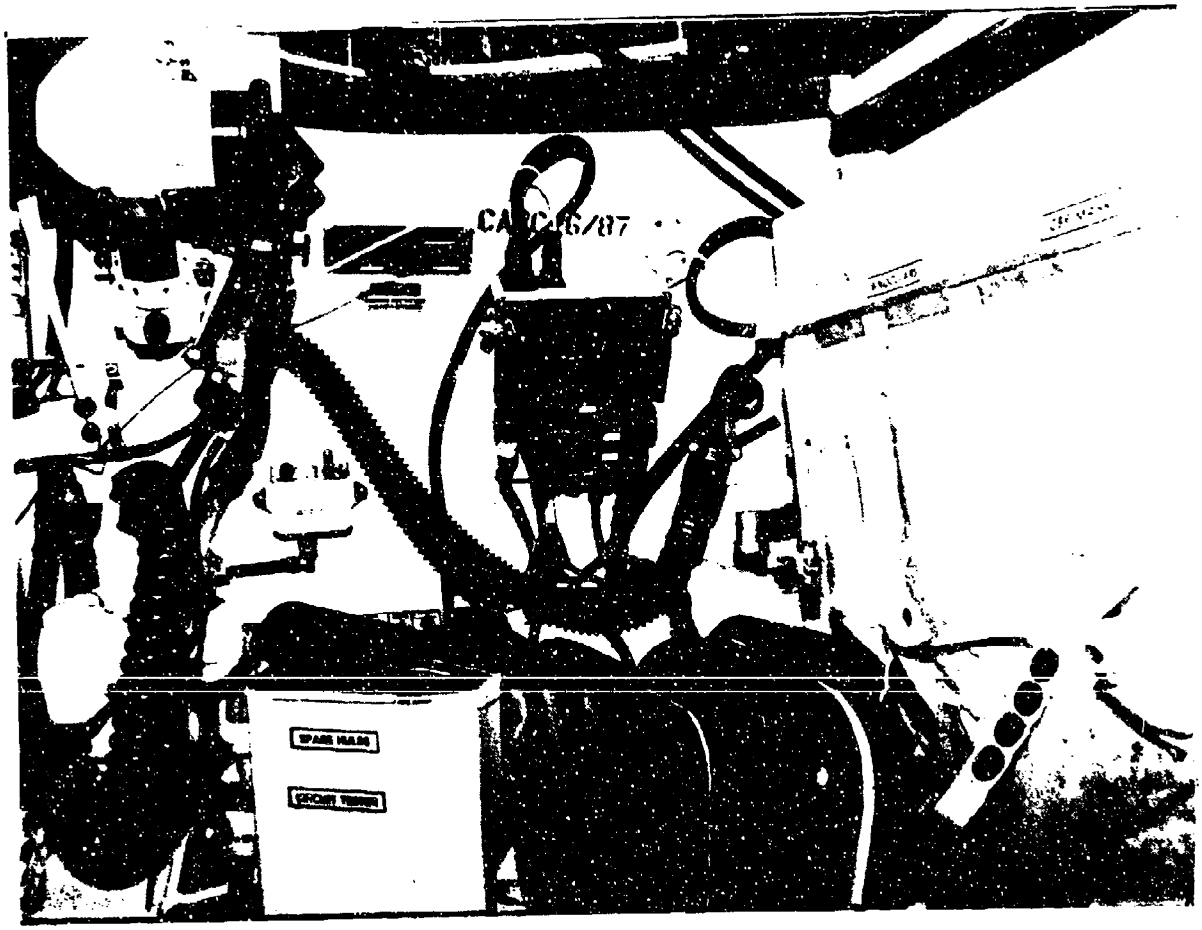


Fig. 5.21 CVIS Installation 3

the LRF is dropped out of the way to reach the rear connector, so that the interface unit cable can be attached in-between. In figures 5.20 & 5.21, the LRF is bolted back up, and the control unit is mounted in the commanders station. The mounting of the interrogator receiver is shown in Figure 5.16. It requires 4 1/4-20 bolts which match the pattern on the ("dog house"). Note the receiver unit GPS would be integrated into the GPS OR LRF unit in a production unit and would not be bolted on top the GPS ("dog house").

Test conditions were generally good (cold and clear). (See Appendix D for weather report).

The overall results of the Ft. Knox test were favorable in that all errors encountered in IFF interrogations have been explained and related to simple solutions. The data from the Ft. Knox test is shown in Tables 5.8 & 5.9).

RANGE TO TARGET: 2167m (meters) START TIME: 12:33

TABLE 5.8

		LASER/INTERROGATOR								RECEIVER/TRANSCEIVER				
Test No.	1	1	Shutter Code	1	Time Code	1	Friend/ Foe	1	1	Shutter Code	1	Time Code	1	Friend/ Foe
1-1		1	0011	1	9994	1	Friend	1	1	0011	1	9994	1	Friend
1-2		1	0011	1	9994	1	Foe	1	1	0011	1	9994	1	Friend
1-3		1	0011	1	9994	1	Friend	1	1	0011	1	9994	1	Friend
1-4		1	0011	1	9994	1	Friend	1	1	0011	1	9994	1	Friend
1-5		1	0011	1	9994	1	Friend	1	1	0011	1	9994	1	Friend
1-6		1	0011	1	9994	1	Foe	1	1	0011	1	9994	1	no reading
1-7		1	0011	1	9994	1	Foe	1	1	0011	1	9994	1	Friend
1-8		1	0011	1	9994	1	Foe	1	1	0011	1	9994	1	Friend
1-9		1	0011	1	9994	1	Friend	1	1	0011	1	9994	1	Friend
1-10		1	0011	1	9994	1	Friend	1	1	0011	1	9994	1	Friend

COMPLETION TIME: 13:00

NOTE: 1-2 GPS reticle jumped off target on pulse 4.
1-6 Foe on first laser pulse-power switch on unit downrange turned off.
1-7 Reticle jump.
1-8 Reticle jump.

MAXIMUM OPERATIONAL DISTANCE TEST

RANGE TO TARGET: 2167 (meters) START TIME: 13:19

TABLE 5.9

LASER/INTERROGATOR				RECEIVER/TRANSCEIVER		
Test No.2	Shutter Code	Time Code	Friend/ Foe	Shutter Code	Time Code	Friend/ Foe
2-1	0010	5553	Friend	0010	5553	Friend
2-2	0010	5553	Friend	0010	5553	Friend
2-3	0010	5553	Foe	0010	5553	no reading
2-4	0010	5553	Friend	0010	5553	Friend
2-5	0010	5553	Friend	0010	5553	Friend
2-6	0010	5553	Friend	0010	5553	Friend

COMPLETION TIME: 13:47

NOTE: 2-3 Tank controller unit not turned on.

5.4 Test Summary

The CVIS system's overall performance met the objectives of the feasibility study. The CVIS hardware was consistently able to function and identify friendly "targets" to the functional extent of the LRF operating abilities. The failures encountered in testing stemmed from three basic errors; 1) Misalignment of the laser due to either the tripod being "bumped" in the off vehicle test, or the reticle jumping off target for superelevation correction in the on vehicle test, 2) Need to recalibrate the CVIS detector at different ranges, which relates to a first problem of boresight difficulties in a tripod system as well as a planned design improvement for time programmed gain in the receiver detector, 3) Human errors in communicating code settings. In some test cases, communication between downrange and uprange was achieved through flashing headlights and waving flags to signal codesettings. Consequently, some tests were flawed by the power being off, improper code settings uprange vs downrange, or Friend or Foe output not being observed. Footnotes have been added to the data tables to indicate these problems rather than discarding the test data.

The overall probability of correct recognition for the Ft. Knox test was [illegible], excluding system failures and calibration, and 70% including the superelevation system failure but excluding calibration, and the one test in which power was turned off completely.

The probability of correctly identifying an enemy is 0 due to the nature of any active cooperative IFF system in that they can only identify the presence of a functional transceiver on board the target.

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Appendix A - Test Plan

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1.0 INTRODUCTION

1.1 Purpose. The purpose of this test program is to establish the system performance of the Combat Vehicle Identification System (CVIS) brassboard in the areas below.

a. Operation of proper IFF codes
b. Rejection of improper codes
c. Maximum/minimum system operating range
d. Receiver transponder field of view
e. Operation in sunlight and darkness
f. Operation in foliate cover
g. Minimum interrogation time
h. Reliability of acquisition at test ranges
i. Ability to "spoof" or jam the system

The objective of the test will be the determination of possible design problems and recommendations of changes to correct them if necessary. There will be no tests made at the subsystem level since the separate components were tested at the time of assembly.

1.2 Equipment Under Test. The equipment consists of two main systems, a tank system and a target system as shown in figure 1. The tank system is the Laser/Interrogator and consists of a control unit, a receiver unit, a power supply, and an interface to a laser range finder test firing box or M1 GPS. The control unit houses a microprocessor and includes a shutter code selector, a time code selector, and friend or foe warning indicators. Contained in the receiver unit is a high speed Nd:YAG detector and signal conditioning electronics. The power supply houses two 12 volt batteries which provide power to the system. The target system is the Receiver/Transponder and consists of a control unit, a transceiver unit, and a power supply. Both the control unit and the power supply are identical to those of the tank system. The transceiver unit contains a multiple high speed Nd:YAG detector system, a high speed electronic shutter, a retro-reflector and supporting electronics.

1.3 Test Approach. Three separate tests are planned for the CVIS brassboard demonstration, each providing data on different system performance characteristics. The first test will be a preliminary functionality test and will occur at a designated area at the TACOM facility. In this test, the two systems will not be mounted on vehicles but will be placed on tripods for convenience. In the second test, a determination of maximum operational range will be made which necessitates the mounting of the target transceiver on a vehicle (rental car,etc.) for ease of measurement. This test will occur at White Sands and will include other measurements as well. The last of the three tests will determine the operating characteristics of the CVIS system when the units are mounted on vehicles. Since the laser/interrogator unit makes use of the laser range finder, this unit must be mounted on an M1. This test will take place at Fort Knox.

1.4 Test Log. The general format of the test log is given in appendix A. All test data will be recorded in the test log and any deviations from the test procedures will be noted. Any special circumstances which might effect the tests results will also be noted.

1.5 Photographic And Video Record. The CVIS brassboard field test, field installation, and system components will be documented with color prints/transparencies, and a video record of the installation and evaluation of the hardware will be made by the photographic department of GDLS with the exception of the TACOM test which will be photographed by TACOM personnel.

2.0 REQUIREMENTS

2.1 Test Equipment. The following is a list of equipment necessary to perform the CVIS evaluation and will be supplied by GDLS except where noted.

- LRF boresighted telescope mounting fixture
- LRF test firing box
- Two tripods or mounting stands
- Power supply - Hewlett Packard 26 volt, 5 amp
- Oscilloscope - Tektronix 7104
- Oscilloscope Camera - Tektronix C-53
- Digital Multimeter
- Two walkie - talkies
- Nd:YAG safety goggles

LRF eyesafe filters: 2.9 O.D., 4.6 O.D.
Find-R-Scope image intensifier
Vehicles (To be supplied by TACOM)
Backdrop for TACOM test (To be supplied by TACOM)

2.2 Test Facilities. CVIS testing will be performed at three different locations; TACOM, White Sands, and Fort Knox. A standard 110 volt, 60 Hz outlet will be necessary at each test facility with the requirement that it is near (< 100 ft) from the laser/interrogator unit. This power is needed to supply the LRF test firing box and oscilloscope. A backdrop will be required for the TACOM tests in order to eliminate backscatter radiation for safety assurance.

2.3 General Test Configuration. The system configuration which will be used for all of the tests is shown if figure 1. In the vehicle mounted tests, the M1 GPS will replace the LRF test firing box. An absorption type filter will be placed on the output window of the laser range finder for the TACOM tests to reduce the energy density of the output pulse to an eyesafe level. In order to reduce testing time, a minimum of interrogation codes will be used. This means that for most of the tests only two codes will be used; one to simulate a friend-friend scenario and one for a friend-foe scenario. These two codes will be kept consistant for the duration of the test.

3.0 TEST PROCEDURE

3.1 TACOM Test. This test is to take place at the TACOM facility. Due to the limited range provided (< 200 yds) a laser filter will be used on the LRF to reduce the energy level of the laser to an eyesafe for safety considerations. Protective laser goggles will still be worn, however, for the duration of the test.

3.1.1 Preparation/Calibration.

a. Mount the LRF/Telescope fixture on a tripod near an electrical outlet (< 100 ft).

b. Mount the CVIS Receiver/Transponder system on a tripod at maximum distance down range in line-of-sight from the LRF.

c. Make all necessary electrical connections to the CVIS Receiver/Transponder system, as shown in fig. 1, and perform a battery check and reset check with the control unit.

d. Set up a backdrop behind the Receiver/Transponder to eliminate any unnecessary backscatter radiation.

e. With the LRF range switch set to "safe" and the eyesafe laser filter installed, make all electrical connections to the CVIS Laser/Interrogator system and the LRF test firing box as shown in fig. 1.

f. Perform a battery check and reset check with the control unit of the Laser/Interrogator system.

g. Connect power supply to the LRF test firing box and plug supply into an electrical outlet.

h. Apply 26 volts to the LRF test firing box and check for any malfunction.

i. Boresight the LRF/Telescope fixture by setting the control unit of the Laser/Interrogator system to fire only one pulse at a time and use a Find-R-Scope to look down range for alignment.

j. Fire laser as necessary for boresighting, pausing for at least 20 sec. between shots.

k. It should be noted that a field calibration of the receiver detectors in the CVIS system may be necessary depending on the laser energy level.

3.1.2 Functionality Test. Two interrogation codes will be used in this test to simulate a friend-friend and a friend-foe situation.

a. Aim the two systems in direct line-of-sight.

b. Set the codes on both control units to the following: Shutter code = 0011, Time code = 7772.

c. Reset both systems.

d. Fire laser, move range switch to "safe", and record results in test log.

e. Set the code of Receiver/Transceiver system to: Shutter code = 0010, Time code = 7772 (Laser/Interrogator system codes remain the same).

f. Reset both systems and wait 2 min. for laser rod cool down.

g. Fire laser, move range switch to "safe", and record results in test log.

h. In the event of erroneous results it may be necessary to adjust system codes or calibrate detectors and retry test. This should be also be recorded.

3.1.3 Angular Field-of-View. In this test, one interrogation code will be used and the Receiver/Transponder system will be rotated until an interrogation error occurs. This will determine the system field-of-view.

a. Aim the two systems in direct line-of-sight.

b. Set the codes on both control units to the following: Shutter code = 0011, Time code = 7772.

c. Reset both systems.

d. Fire laser, move range switch to "safe" and wait 2 min. for laser rod cool down.

e. Move the Receiver/Transponder system angularly off axis in increments of 10 degrees and repeat step (d) until an error occurs and the systems do appear as friends.

f. Record angle in test log where error occurs.

3.1.4 Minimum Interrogation Time. To determine the minimum time for interrogation the a minimum time code will be assumed and based on the results using this code, an adjustment will be made in the time code until the minimum is found. The purpose of this approach is to minimize the overall time of this test.

a. Aim the two systems in direct line-of-sight.

b. Set the codes on both control units to the following: Shutter code = 0011, Time code = 2222 (Assumed shortest time code).

c. Reset both systems.

d. Fire laser, move range switch to "safe" and wait 2 min. for laser rod cool down.

e. If an error occurs and the systems appear unfriendly then set the time codes of the control units to the next longer time, i.e. from 2222 to 3333. Otherwise, set the time codes to the next shorter time.

f. Repeat steps (c) - (e) until the minimum interrogation time is determined and record this in test log.

3.1.5 Minimum Operational Distance. This test is designed to determine the minumum spacing between the CVIS units before a system failure occurs.

a. Move the Receiver/Transceiver system to a point half of its present distance from the Laser/Interrogator system.

b. Aim the two systems in direct line-of-sight.

c. Set the code of the Laser/Interrogator to the following: Shutter code = 0011, Time code = 7772.

d. Set the code of the Receiver/Transceiver to the following: Shutter code = 0010, Time code = 7772.

e. Reset both systems.

f. Fire laser, move range switch to "safe" and wait 2 min. for laser rod cool down.

g. If an error occurs and the target appears friendly, then move the Receiver/Transceiver half of its present dis tance from the Laser/Interrogator away from its current position. Otherwise, move the Receiver/Transceiver half of its present distance from the Laser/Interrogator towards the Laser/Interrogator.

h. Repeat steps (b)-(g) until the minimum operational distance between the two systems is determined and record this in the test log.

3.2 White Sands Test. This test is to take place at White Sands, New Mexico with the main purpose of determining the maximum operation distance of the CVIS system. Other tests include operation in darkness and an attempt at jamming the system.

Laser safety goggles must be worn for the duration of this test.

3.2.1 Preparation/Calibration.

a. Mount the LRF/Telescope fixture on a tripod near an electrical outlet (< 100 ft).

b. Mount the CVIS Receiver/Transceiver on a vehicle (rental car, etc.) with tie-down staps so that it can easily be moved down range.

c. Make all necessary electrical connections to the CVIS Receiver/Transceiver system, as shown in fig. 1, and perform a battery check and reset check with the control unit.

d. With the LRF range switch set to "safe", make all electrical connections to the CVIS Laser/Interrogator system and the LRF test firing box as shown in fig. 1.

e. Perform a battery check and reset check with the control unit of the Laser/Interrogator system.

f. Connect the power supply to the LRF test firing box and plug supply into an electrical outlet.

g. Apply 26 volts to the LRF test firing box and check for any malfunction.

h. Check the boresight of the LRF/Telescope fixture by setting the control unit of the Laser/Interrogator system to fire only one pulse at a time and using a Find-R-Scope to look down range for alignment.

i. It should be noted that a field calibration of the receiver detectors in the CVIS system may be necessary due to the change in laser energy levels from the last test.

3.2.2 Maximum Operational Distance. For ease of mobility, the Receiver/Transceiver will be mounted on a vehicle so that it can be moved long distances down range. Data will be taken at three ranges (1.0, 1.5, and 2.0 km) in addition to the determination of maximum range. Two interrogation codes will be used in this test to simulate a friend-friend and a friend-foe situation.

a. Move the Receiver/Transceiver system to a distance of

1.0 km. from t·e Laser/Interrogator system.

b. Set the codes ı both control units to the following: Shutter code 0011, Time code = 7772.

c. Reset both systems.

d. Aim the two systems in direct line-of-sight.

e. Fire laser, move range switch to "safe" and record results in test log.

f. Set the code of Receiver/Transceiver system to: Shutter code = 0010, Time code = 7772 (Laser/Interrogator system codes remain the same).

g. Reset both systems and wait 2 min. for laser rod cool down.

h. Fire laser, move range switch to "safe" and record results in test log.

i. In the event of erroneous results it may be necessary to adjust system codes or calibrate detectors and retry test. This should be also be recorded.

j. Move the Receiver/Transceiver system to distances of 1.5 and 2.0 km. away from the Laser/Interrogator system and repeat steps (b)-(i).

k. Move the Receiver/Transceiver system to a position for determining the maximum operating range of the system based on the data taken at 1.0, 1.5, and 2.0 km. This position will either be greater than or less than 2.0 km., and several points might have to be tested to determine the failure range.

l. Record range in test log where failure occurs.

3.2.3 Darkness Test. The darkness test is design to determine system performance at night. The range chosen for this test is 1.0 km. and appropriate time must be allocated for this nighttime test.

a. Move the Receiver/Transceiver system to a distance of 1.0 km. from the Laser/Interrogator system.

b. Set the codes on both control units to the following: Shutter code = 0011, Time code = 7772.

c. Reset both systems.

d. Aim the two systems in direct line-of-sight.

e. Fire laser, move range switch to "safe" and record results in test log.

f. Set the code of Receiver/Transceiver system to: Shutter code = 0010, Time code = 7772 (Laser/Interrogator system codes remain the same).

g. Reset both systems and wait 2 min. for laser rod cool down.

h. Fire laser, move range switch to "safe" and record results in test log.

i. In the event of erroneous results it may be necessary to adjust system codes or calibrate detectors and retry test. This should be also be recorded.

3.2.4 <u>System "Spoof" Attempt</u>. In this test, the ability to jam or fool the CVIS system will be considered. A corner-cube reflector will be used to try to cause errors in the laser return pulse code.

a. Move the Receiver/Transceiver system to a distance of 1.0 km. from the Laser/Interrogator system.

b. Mount the corner-cube relfector on the Receiver/Transceiver system so that it is aimed in the same direction as the transceiver unit and close to the output window.

c. Set the codes on both control units to the following: Shutter code = 0010, Time code = 7772.

d. Reset both systems.

e. Aim the two systems in direct l.... of-sight.

f. Fire laser and record results in test log.

3.3 <u>Fort Knox Test</u>. This test is to take place at Fort Knox, Kentucky with the objective of measuring the CVIS system performance when incorporated into army vehicles, i.e. M1. Tests will include maximum operational distance, operation when vehicles are camouflaged, and effectiveness when the target vehicle is orientated sideways to the interrogating vehicle.

Laser safety goggles must be worn for the duration of this test.

3.3.1 Preparation/Calibration.

a. Mount the receiver unit of the Laser/Interrogator system on the dog house of the GPS on the designated M1 using tie-down straps to secure it into place so it is aimed in the same line of sight as the GPS.

b. Mount the transceiver unit of the Receiver/Transceiver system on the target vehicle (M1) in the same fashion as in step (a).

c. Make all necessary electrical connections to the CVIS Receiver/Transceiver system, as shown in fig. 1, and perform a battery check and reset check with the control unit.

d. With the LRF range switch set to "safe", make all electrical connections to the CVIS Laser/Interrogator system and the GPS.

e. Perform a battery check and reset check with the control unit of the Laser/Interrogator system.

f. Field calibration of the receiver detectors in the CVIS system should not be necessary if the White Sands test has previously taken place.

3.3.2 Maximum Operational Distance. Data will be taken at three ranges (1.0, 1.5, and 2.0 km) in addition to the determination of maximum range. Two interrogation codes will be used in this test to simulate a friend-friend and a friend-foe situation.

a. Move the target vehicle to a distance of 1.0 km. from the Laser/Interrogator vehicle and in a position sideways with respect to this vehicle.

b. Aim the two systems in direct line-of-sight.

c. Set the codes on both control units to the following: Shutter code = 0011, Time code = 7772.

d. Reset both systems.

e. Fire laser, move range switch to "safe" and record results in test log.

f. Set the code of Receiver/Transceiver system to: Shutter code = 0010, Time code = 7772 (Laser/Interrogator system codes remain the same).

g. Reset both systems and wait 2 min. for laser rod cool down.

h. Fire laser, move range switch to "safe" and record results in test log.

i. Move the target vehicle to distances of 1.5 and 2.0 km. away from the Laser/Interrogator vehicle and repeat steps (b)-(h).

j. Move the target vehicle to a position for determining the maximum operating range of the system based on the data taken at 1.0, 1.5, and 2.0 km. This position will either be greater than or less than 2.0 km., and several points might have to be tested to determine the failure range.

k. Record range in test log where failure occurs.

3.3.3 Foliate Cover Test. The target vehicle will be moved behind foliate cover or camouflaged in some manner to test the effectiveness of the CVIS system under these conditions.

a. Move the target vehicle to a distance of 1.0 km. from the Laser/Interrogator vehicle and in a position sideways with respect to this vehicle.

b. Camouflage the target vehicle in an appropriate manner, either by moving it behind foliate cover, or by using a camouflage netting.

c. Aim the two systems in direct line-of-sight.

d. Set the codes on both control units to the following: Shutter code = 0011, Time code = 7772.

e. Reset both systems.

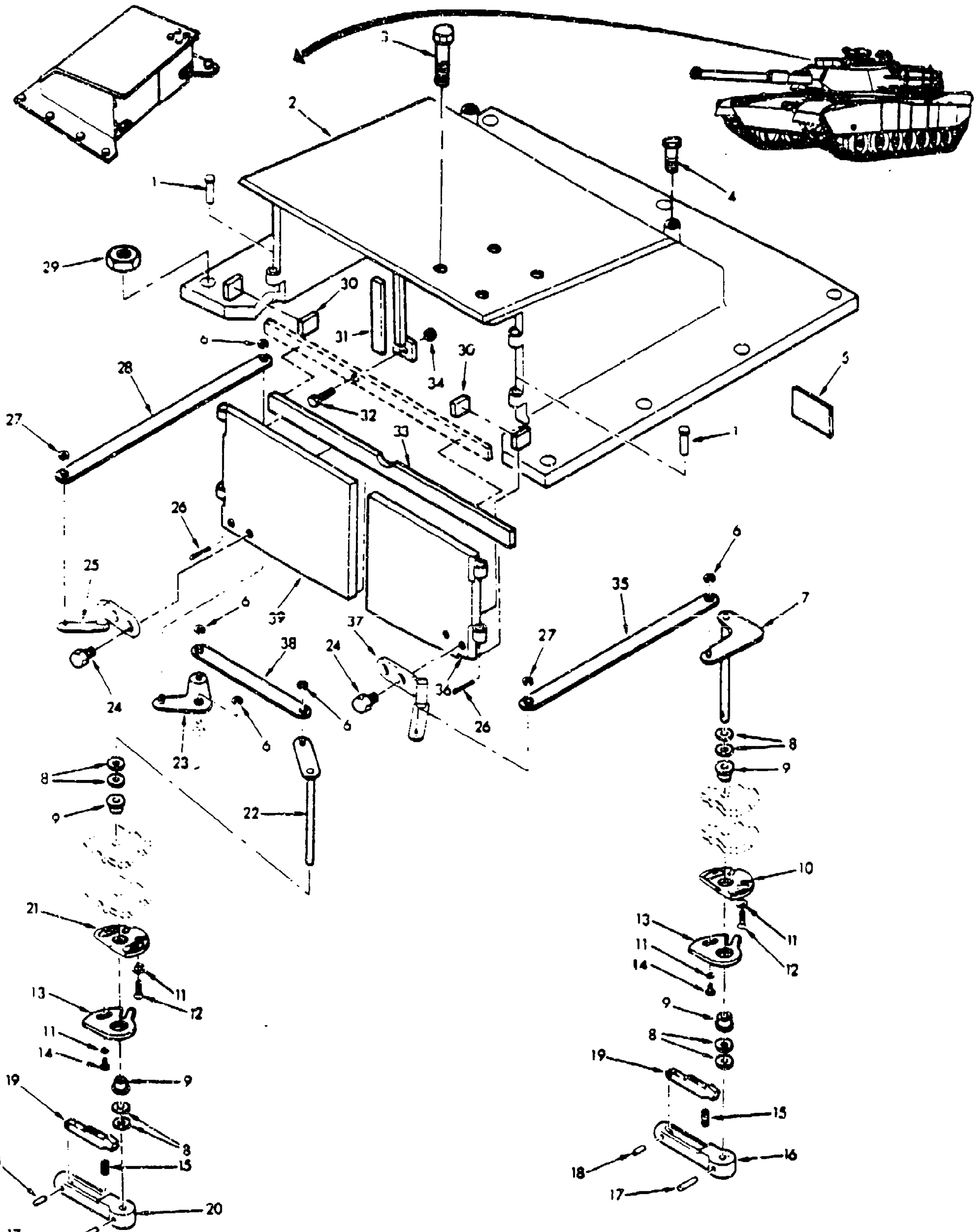
f. Fire laser, move range switch to "safe" and record results in test log.

g. Set the code of Receiver/Transceiver system to: Shutter code = 0010, Time code = 7772 (Laser/Interrogator system codes remain the same).

h. Reset both systems and wait 2 min. for laser rod cool down.

i. Fire laser, move range switch to "safe" and record results in test log.

j. Note that the camouflaging of the target vehicle should be such that normal operation of the laser range finder will not be impared.


34P2-164R3

CVIS TEST LOG

1.0 TACOM Test.

1.1 Preparation/Calibration.

Notes:

1.2 Functionality Test.

		Laser/Interrogator				Receiver/Transceiver		
Test No.		Shutter Code	Time Code	Friend/ Foe		Shutter Code	Time Code	Friend/ Foe

Notes:

Appendix B - Circuit Descriptions

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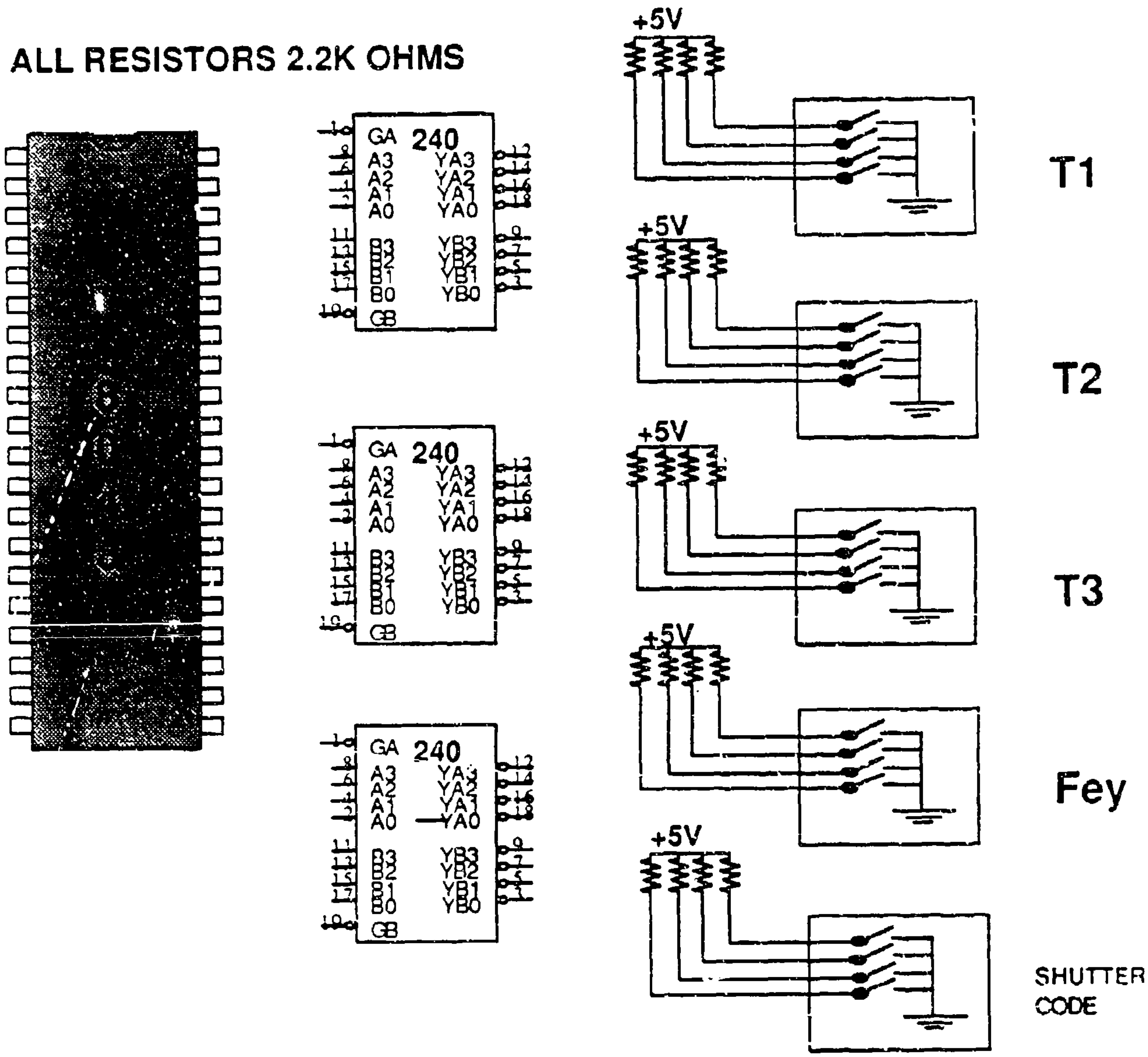
CONTROLLER CIRCUIT

PAGE 1 OF 4

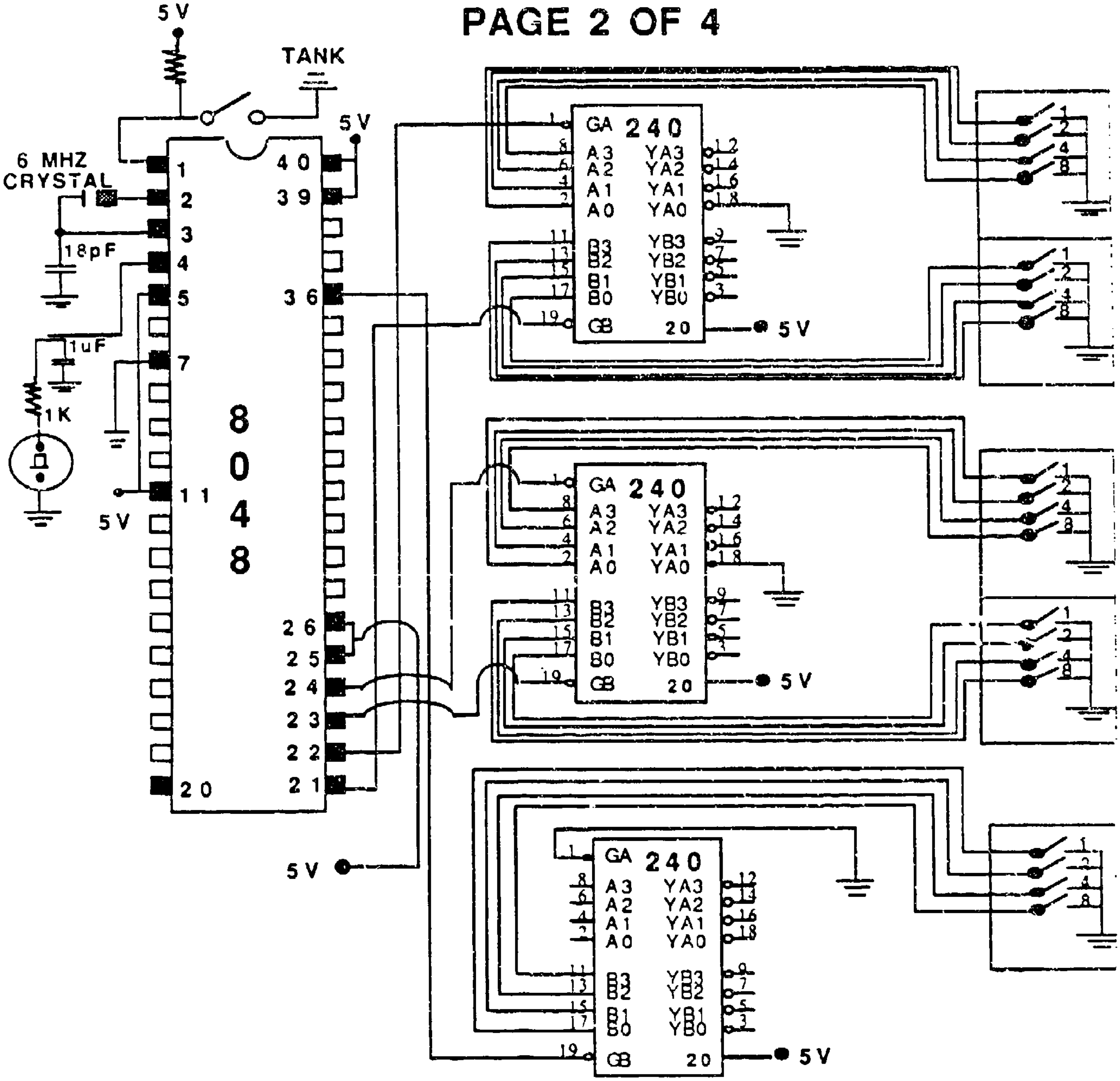
ALL RESISTORS 2.2K OHMS



THIS DIAGRAM DEPICTS ALL SWITCHED INPUTS TO THE MICROPROCESSOR WITH PULLUPS. THE INPUTS ARE ROUTED THROUGH DUAL DIRECTION BUS TRANSCEIVERS TO THE MICROPROCESSOR IN THE FOLLOWING DIAGRAMS.

CONTROLLER CIRCUIT

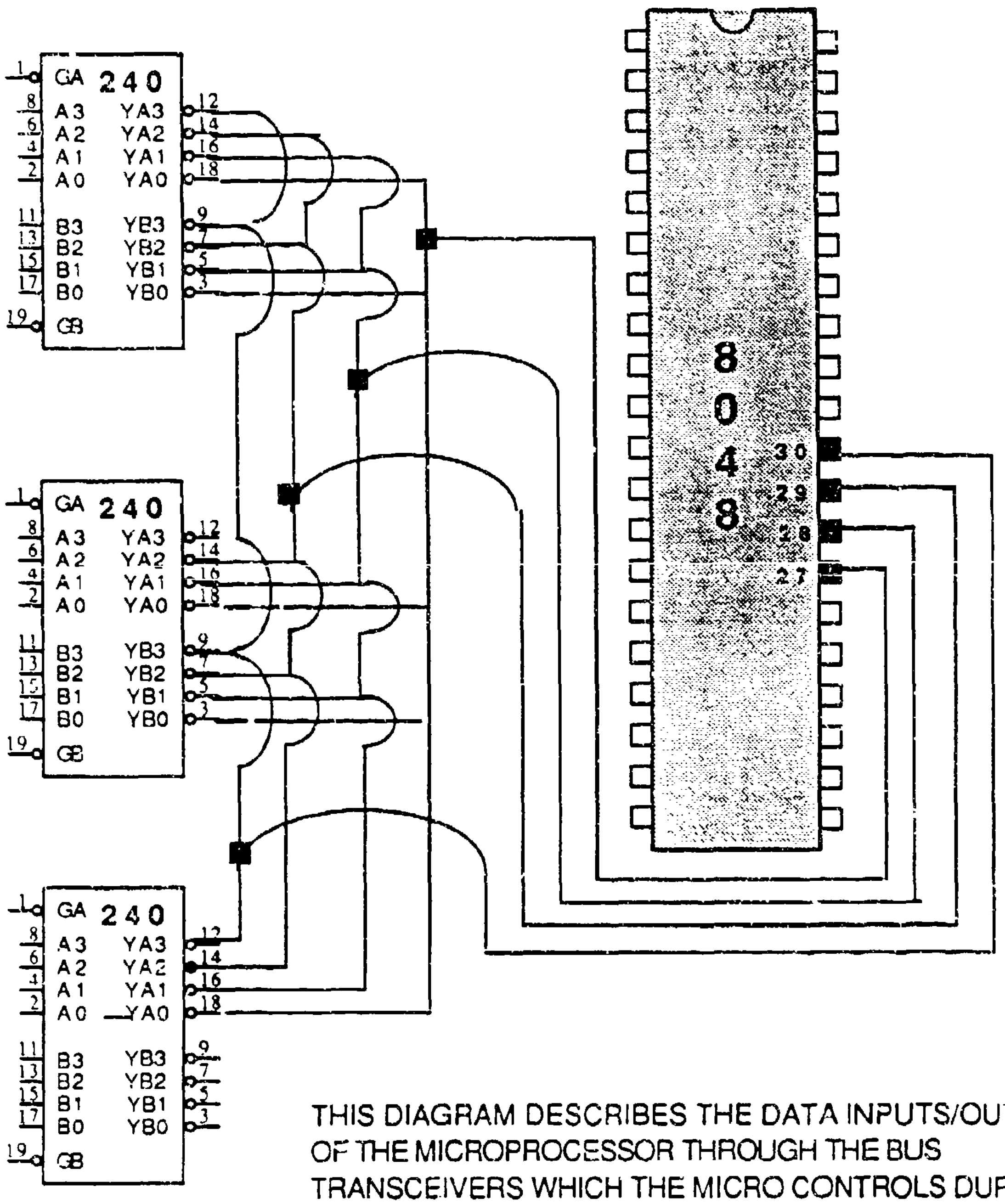
PAGE 2 OF 4



THIS DIAGRAM DESCRIBES THE INTERCONNECTIONS OF THE 4 CODE SELECTION SWITCHES TO THE MICROPROCESSOR AS WELL AS THE CRYSTAL OSCILLATOR-CLOCK CIRCUIT

CONTROLLER CIRCUIT

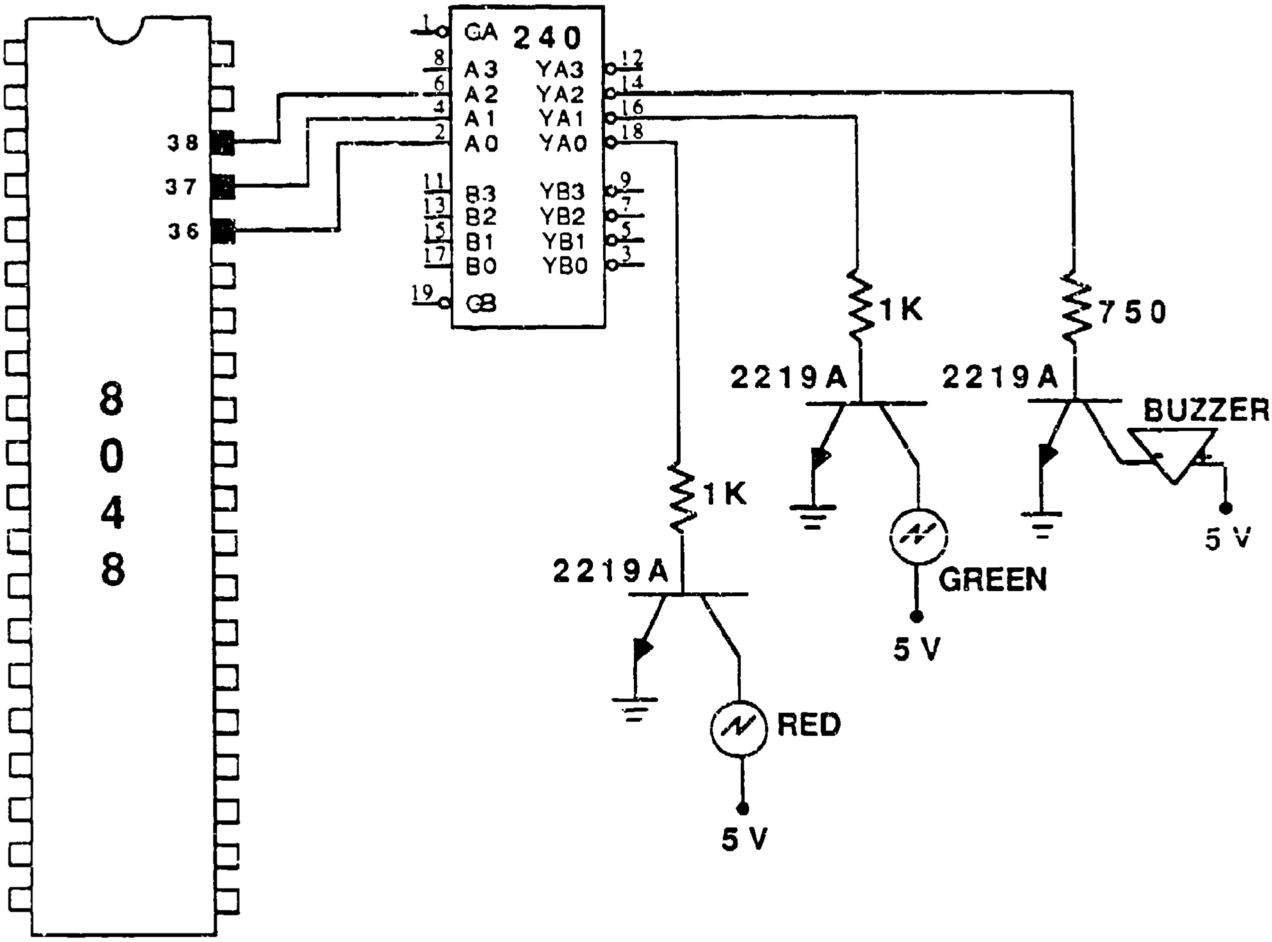
PAGE 3 OF 4



THIS DIAGRAM DESCRIBES THE DATA INPUTS/OUTPUTS OF THE MICROPROCESSOR THROUGH THE BUS TRANSCEIVERS WHICH THE MICRO CONTROLS DURING THE IFF SEQUENCE.

CONTROLLER CIRCUIT

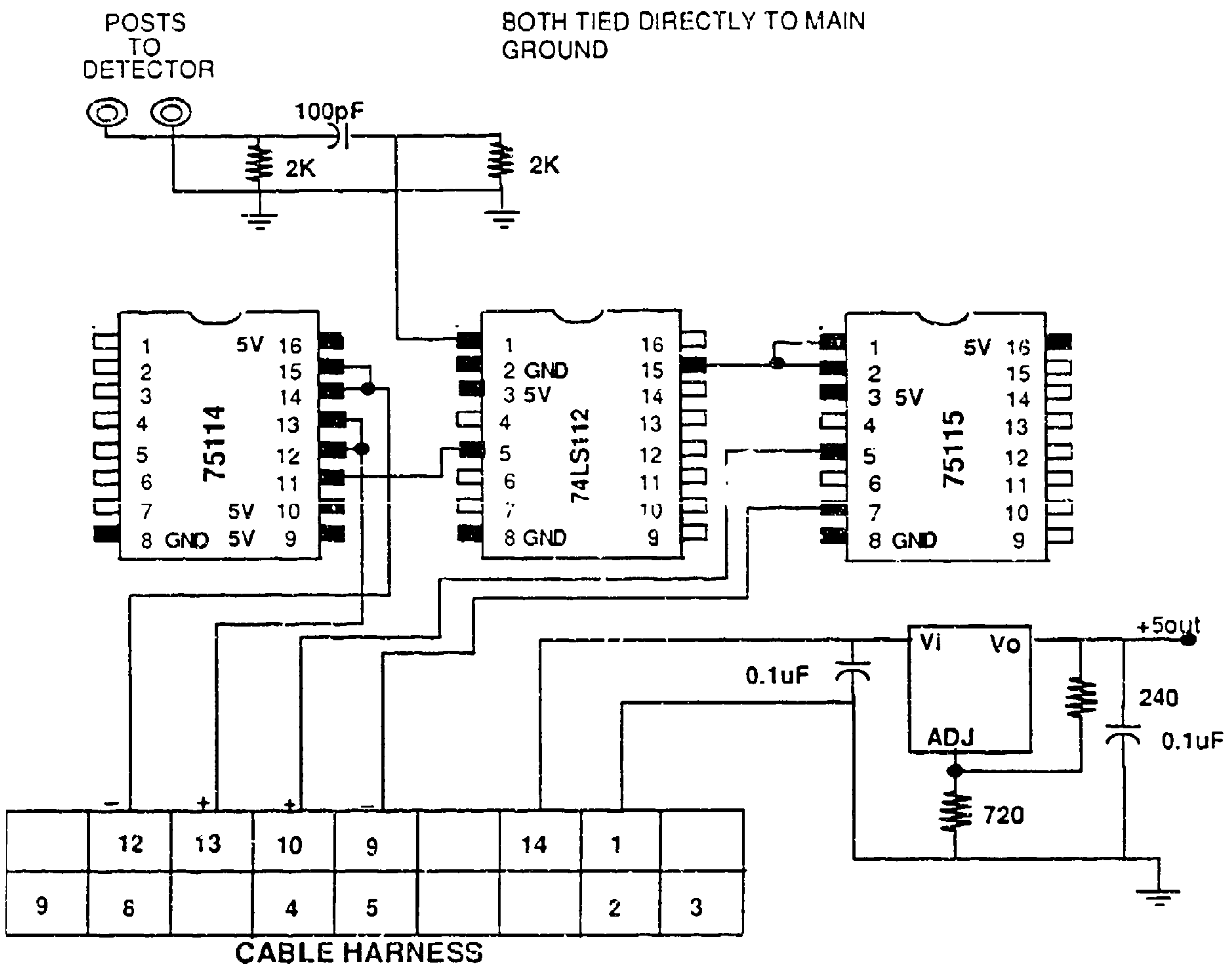
PAGE 4 OF 4



THIS DIAGRAM DESCRIBES THE MICROPROCESSOR OUTPUTS WHICH IN TURN INITIATE A SINGLE TRANSISTOR DRIVER STAGE FOR THE FRIEND AND FOE LIGHTS AS WELL AS THE BUZZER.

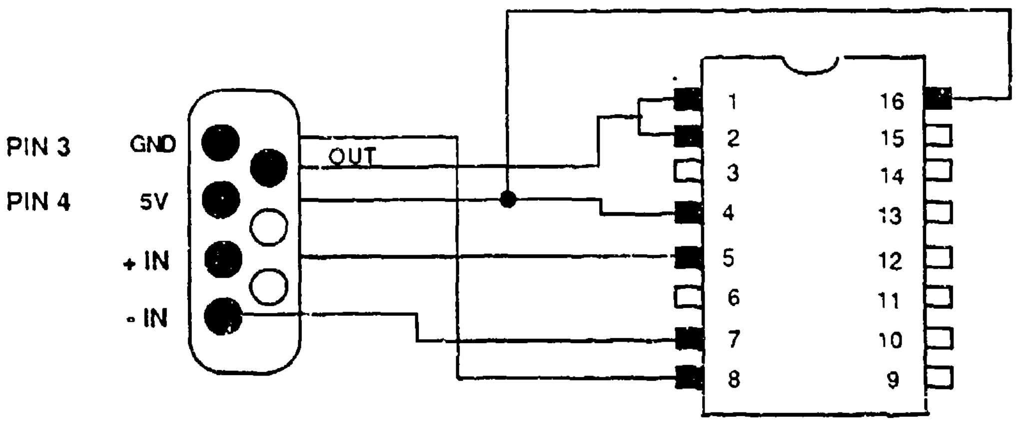
DIFF RECEIVER AND THRESHOLD CIRCUIT

(Target)



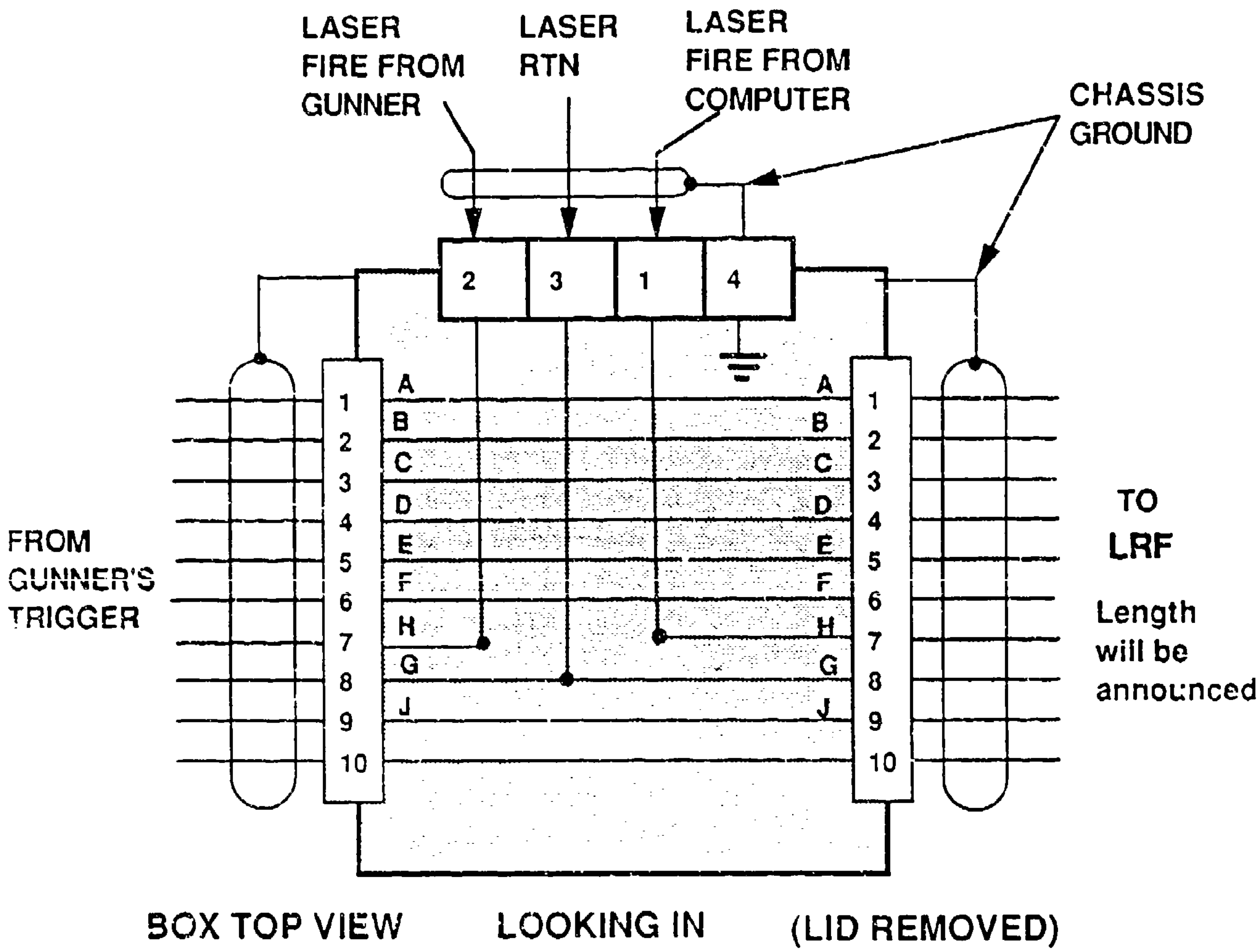
THIS CIRCUIT DIAGRAM DESCRIBES THE DETECTION CIRCUIT AT THE TARGET TRANSCEIVER AS WELL AS THE DIFFERENTIAL RECEIVER AND DRIVER USED TO TRANSFER THE INFORMATION AND FACILITATE RESETING THE DETECTOR LATCH BY THE MICROPROCESSOR

SHUTTER DIFF RECEIVER



THIS DIAGRAM DESCRIBES THE CONNECTIONS USED TO RECEIVE THE DIFFERENTIAL DRIVER SIGNALS FROM THE MICROPROCESSOR TO TRIGGER THE SHUTTER IN THE TARGET TRANSCEIVER

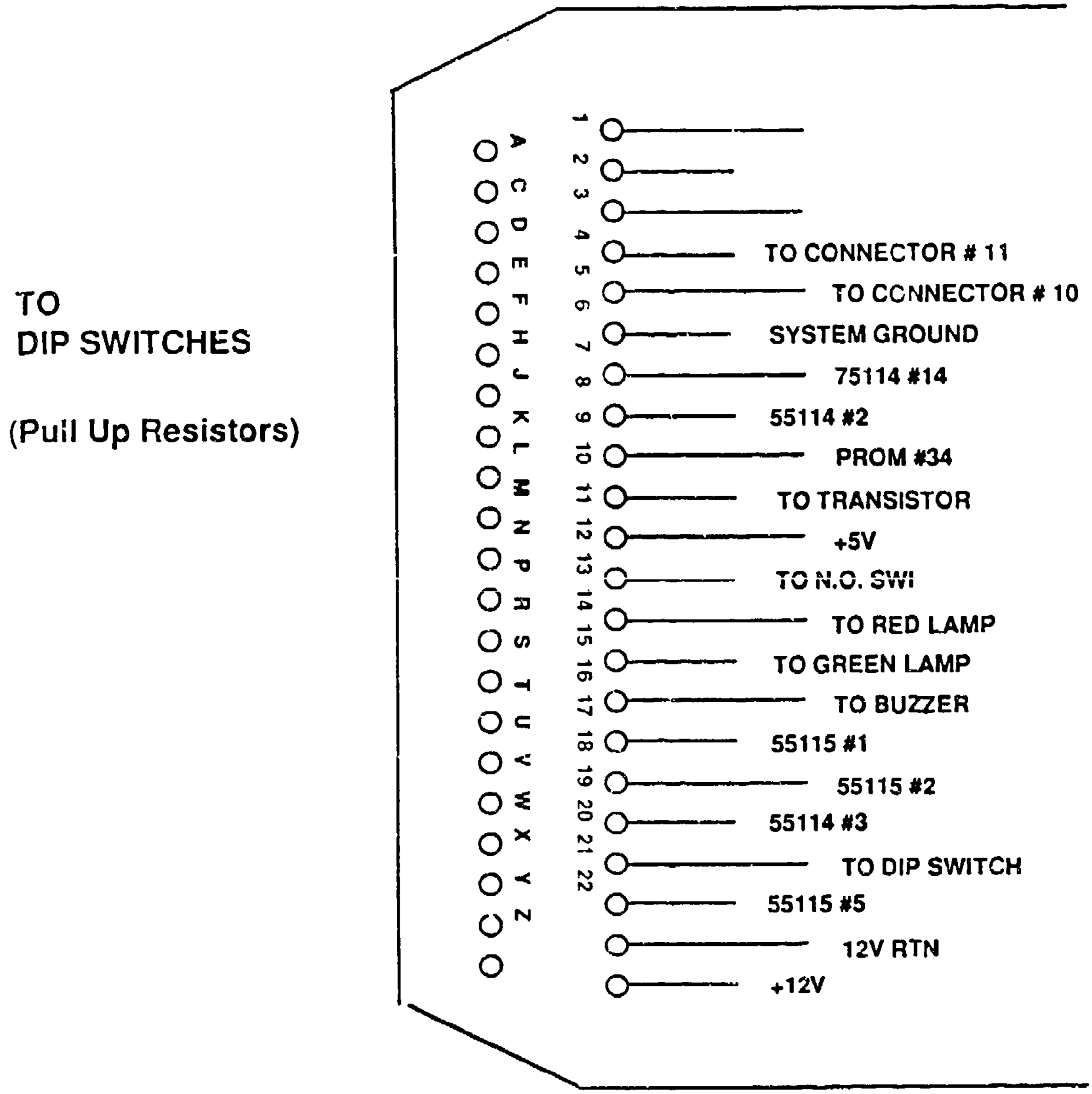
LASER FIRE INTERFACE BOX



THIS WIRING DIAGRAM DISPLAYS THE CVIS "SPLICE" INTO THE M1 LASER FIRE HARNESS. THE CONNECTION GIVES THE MICROPROCESSOR CONTROL OVER THE LASER FIRING AND ALLOWS IT TO MONITOR THE GUNNER'S LASER FIRE COMMAND.

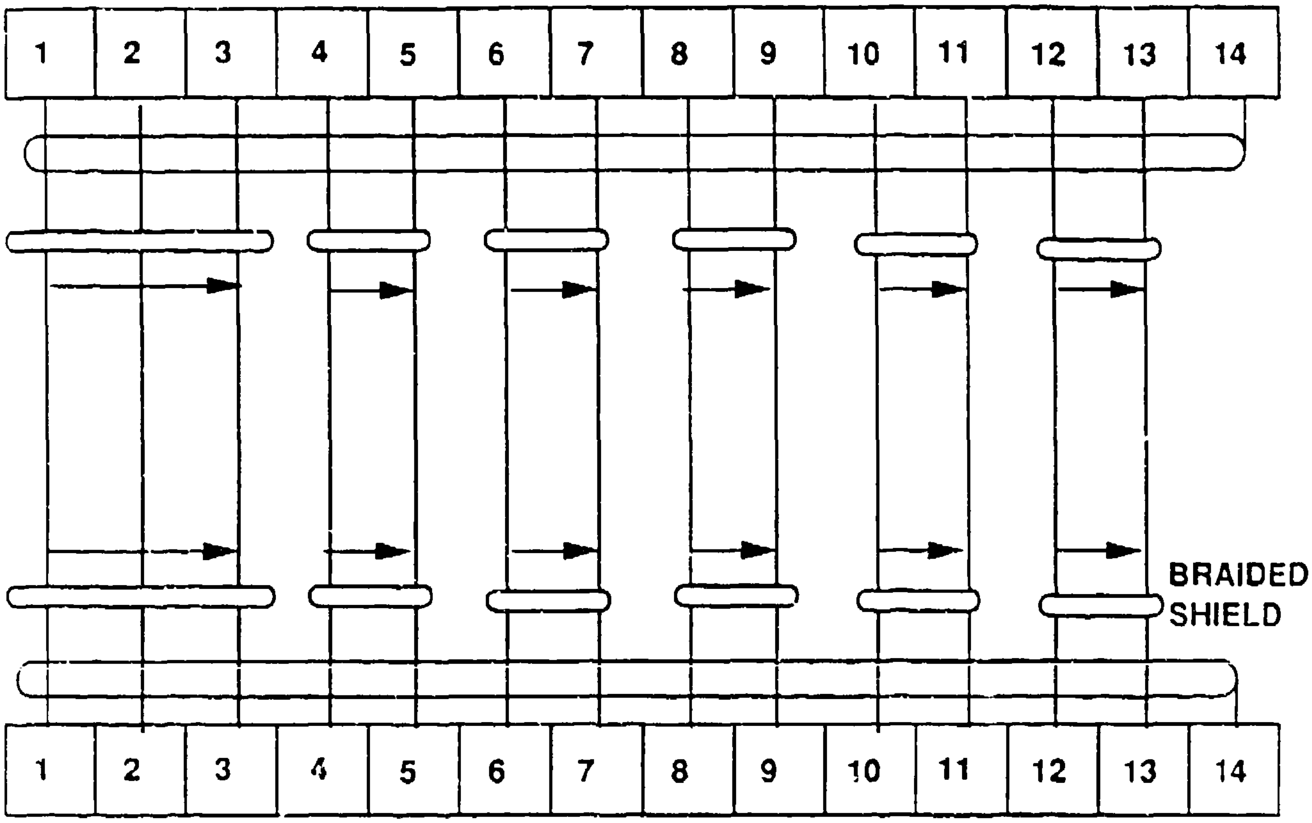
MAIN CONTROLLER BOARD

Edge card pinout



THIS DIAGRAM SHOWS THE PINOUT OF THE CONTROLLER UNIT EDGE CARD WHICH CONTAINS THE MICROPROCESSOR.

CVIS
COMMON CABLE HARNESS



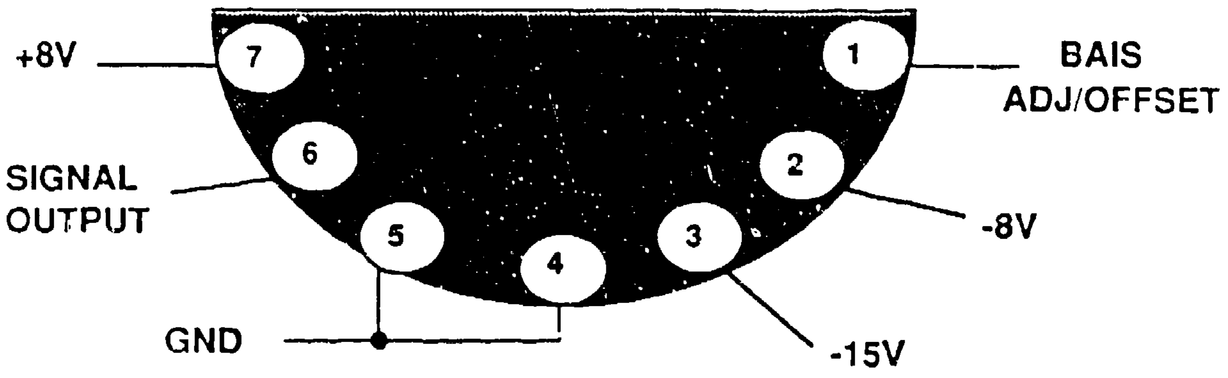
AMP 14 PIN PLUG

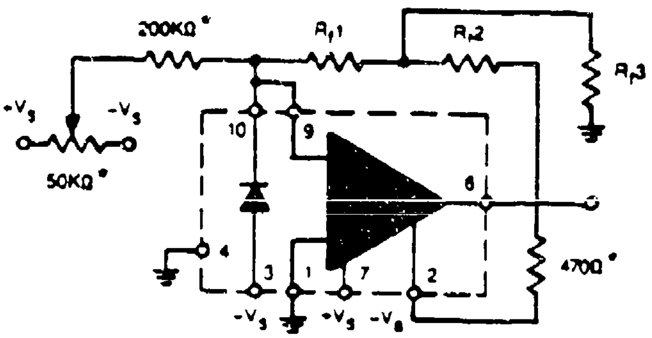
2 20 FOOT
1 10 FOOT
4 COPIES TOTAL

THIS WIRING DIAGRAM SHOWS THE CONSTRUCTION OF THE CVIS CABLES, ALL ARE WIRED TO THIS SPECIFICATION.

HYBRID DETECTOR PINOUT

Rear View





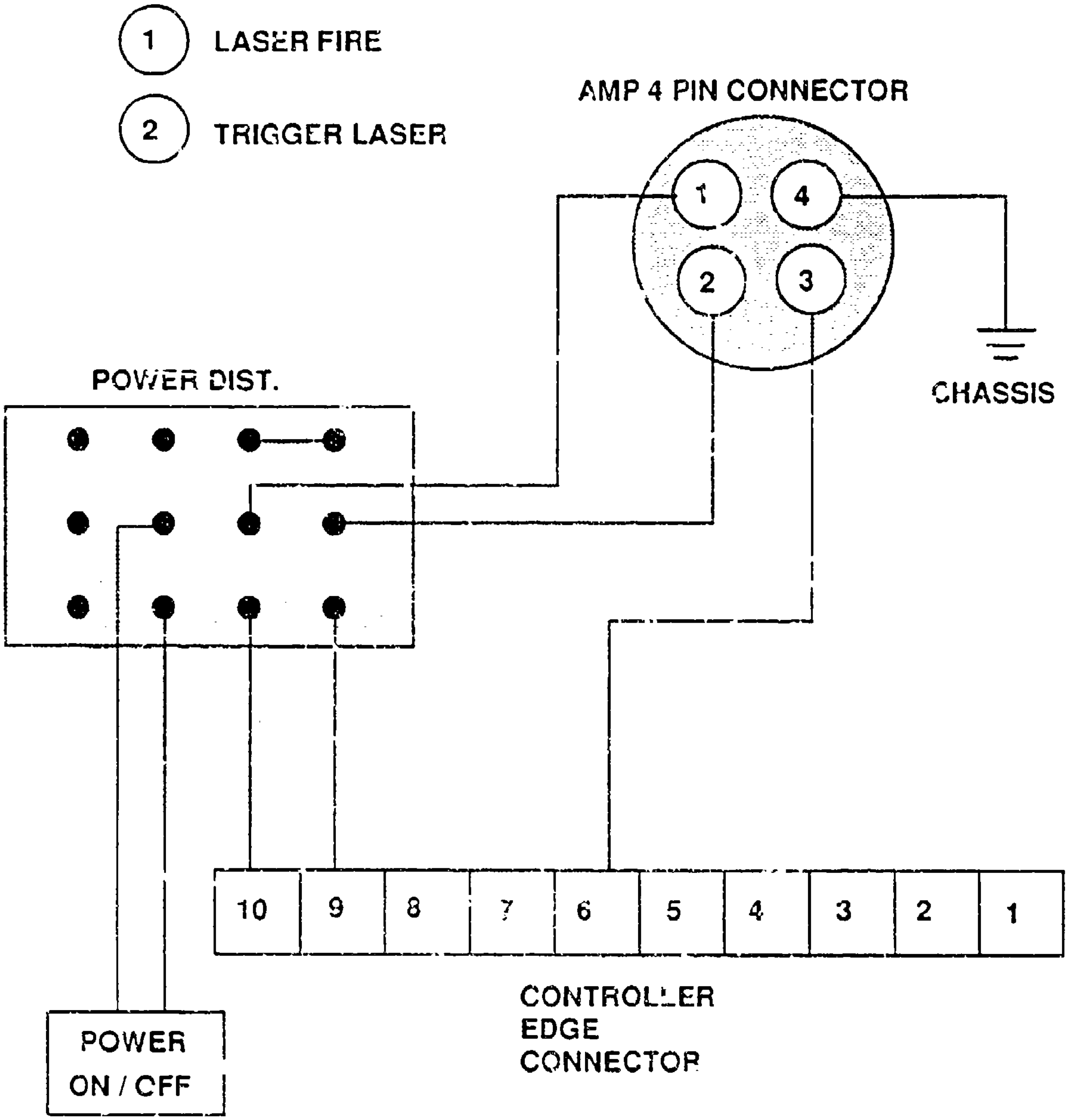
"T" Feedback Loop

Pin Assignments

1	Signal Ground (+in)	6	Output
2	−V Supply	7	+V Supply
3	−V Bias (Anode)	8	Compensation
4	Case Ground	9	Inverting Input
5	Not Connected	10	Cathode

THIS DIAGRAM GIVES THE SCHEMATIC AND CARD PINOUT OF THE HYBRID DETECTOR CIRCUIT USED IN THE TANK RECEIVER UNIT.

LASER INTERFACE



THIS SCHEMATIC DEPICTS THE CABLE INTERCONNECT FROM THE TANK CONTROLLER UNIT TO THE LASER INTERFACE UNIT.

PORT AND BUS INFORMATION

INPUT PORT

PIN #	PORT 1	
10	0 = 1's	1/P
11	1 = 2's	1/P
12	2 = 4's	1/P
13	3 = 8's	1/P
14	4 =	
15	5 =	
16	6 = LASER FIRE SIGNAL FROM GUNNER	
17	7 = LASER REC'D SIGNAL BOTH TARGET & TANK	

OUTPUT PORT

PIN #	PORT 2	
21	0 = I_1	$\overline{EN}$
22	1 = I_2	$\overline{EN}$
23	2 = I_3	$\overline{EN}$
24	3 = O	
35	4 = SHUTTER CODE	$\overline{EN}$
36	5 = RED LIGHT	$\overline{EN}$
37	6 = GREEN LIGHT	$\overline{EN}$
38	7 = BUZZER	$\overline{EN}$

DATA BUS

PIN #	
12	0 = SHUTTER CONTROL (TARGET) ECL PWR UP (TANK)
13	1 = ECL RESET (TANK) LASER SIGNAL R' 'ET (TARGET) LASER SIGNA:
14	2 = LASER FIRE (TANK ONLY)
15	3 =
16	4 =
17	5 =
18	6 =
19	7 =

Appendix C - LRF Specifications

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Laser Rangefinder (LRF)

The purpose of the laser rangefinder is exactly what the name implies, i.e. to determine the distance between two objects. It does this by sending a short pulse of laser light at a target and receiving the reflected light from the target. It measures the time between the moments of transmission and reception and converts this into range data. Clearly, for minimal error, the transmitted pulse should be well defined and of short duration.

The M1 laser rangefinder uses a dye Q-switched, neodymium doped YAG laser ($Y_3Al_5O_{12}:Nd^{3+}$) with an output wavelength of 1.06 microns. The output pulse width is of the order of 8 nanoseconds. This is easily within the limits needed for a $\pm$10 meter range accuracy. Its operating range is from 200 to 7990 meters (0.1 to 4.8 miles). The method used to determine the actual range is quite simple. The rangefinder employs a counter which is triggered at a rate (15 MHz) such that, in the time between each count, the pulse travels 20 meters. Thus, each count represents a change of 10 meters in the range. Remember, the laser pulse travels from the tank to the target. It bounces off the target. Some of it is reflected back to the tank. The portion that reaches the tank and stops the counter has traveled twice the distance between the tank and the target. Therefore, the counter must count one ten-meter for every 20 meters the light travels. Since light travels at 3×10^8 meters per second, the counter must count $(3 \times 10^8/20)$ meters per second. This means 1.5×10^7 counts per second or a 15 MHz clock.

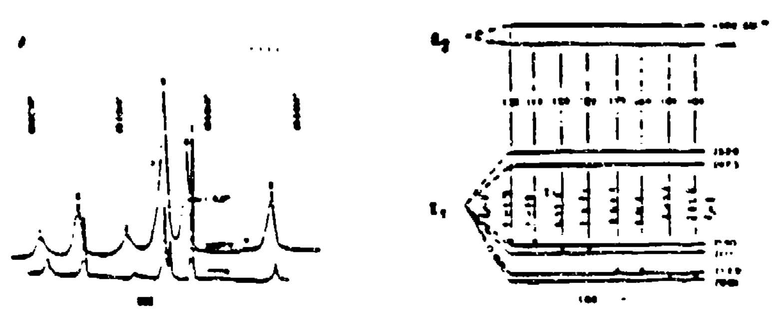
As mentioned above, the laser rod itself is an yttrium aluminum garnet (YAG) laser doped with neodymium (Nd) (1.1 $\pm$0.1 atomic percent). The laser output is due to transitions in the trivalent neodymium. The most intense line is at 1.06 μ. (See Figure 12). A typical output energy is 40 millijoules through a beam divergence angle of 0.5 milliradians. (See Table I.)

1.5 M AT 1000 METERS

FIGURE 12:

(a) THE FLUORESCENCE SPECTRUM OF Nd^{3+} IN YAG AT 77° AND 300°K IN THE REGION ABOUT 1.06 μ.

(b) THE TRANSITION ENERGY LEVELS OF Nd^{3+} IN YAG.



PERFORMANCE CHARACTERISTICS OF THE M1 LRF

Range Characteristics	
Operating Range	200 to 7990 meters
Accuracy	±10 meters
Target Resolution	20 meters
Range Data	Parallel Output (BCD)
Data Update Rate	Once per Ranging Cycle
Optical Characteristics	
Transmitter	
Output pulse energy	40 millijoules typical
Output pulse width	8 nanoseconds
Output beam divergence	32 millijoules through beam divergence angle of 0.5 milliradians
Pulse repetition rate	3 pulses per minute (average)
Laser wavelength	1060 nanometers
Laser type	Nd:YAG, Dye Q-switched
Receiver	
Field of View	500 microradians
Power Requirements	
Voltage	18 to 30 Vdc
Current	Less than 3 amperes (Standby) Less than 5 amperes (Laser Firing)
Operating	
Vibration	2G, 5 to 500 Hz
Shock, Basic	30G, 11 milliseconds
Temperature	-32° to +60°C
Humidity	5 to 100 percent

SAFE and then to the ARM FIRST RTN positions. Remove prime power. Verify that the LRF did not fire. Reapply prime power. Set the RANGE switch to the SAFE and then ARM LAST RTN positions. Remove prime power. Verify that the LRF did not fire.

4.2.1.3 Signals

4.2.1.3.1 Laser fire signal. While performing the tests of 4.2.1.2.3 and 4.2.1.2.4, verify that the requirement.of 3.2.1.3.1 is met.

4.2.1.3.2 Range Ready signal. While performing the tests of 4.2.1.2.3c and 4.2.1.2.4c, verify that the requirement of 3.2.1.3.2 is met.

4.2.1.3.2.1 Multiple Returns. [The following test shall be performed with a 1.5 db ±20 percent filter (3.0 db 2-way) placed in front of the objective lens at an angle of 2° - 5° from the normal to the beam axis.] Repeat the lasing operation of 4.1.3.3c at a single target. Verify that the multiple returns signal is high in accordance with 3.2.1.3.2.1. Aim the LRF at two targets of known ranges (Item 4.1, Table I) spaced 20 ±1 meters apart in the line of sight (both targets within the range window specified) such that the targets are intercepted equally by the reticle. Set the RANGE switch in the ARM FIRST RTN position, then in the ARM LAST RTN position and repeat the lasing operation in each switch position. Verify that the multiple returns signal is low in accordance with 3.2.1.3.2.1 for both conditions.

4.2.1.3.2.2 First/last return logic. While performing the tests of 4.2.1.3.2.1 with the RANGE switch in the ARM FIRST RTN position, verify that the range bits are equivalent to the known first target range ±10 meters. While performing the tests of 4.2.1.3.2.1 with the RANGE switch in the ARM LAST RTN position, verify that the range bits are equivalent to the known last target range ±10 meters. The LRF shall be fired a minimum of ten times in each switch position. A minimum of twenty seconds shall be maintained between successive pulses.

c. LAST RTN. Repeat the sequence of 4.2.1.3.5b with the RANGE switch in the ARM LAST RTN position. Verify that the requirements of 3.2.1.3.5 are met, and that a valid range is received.

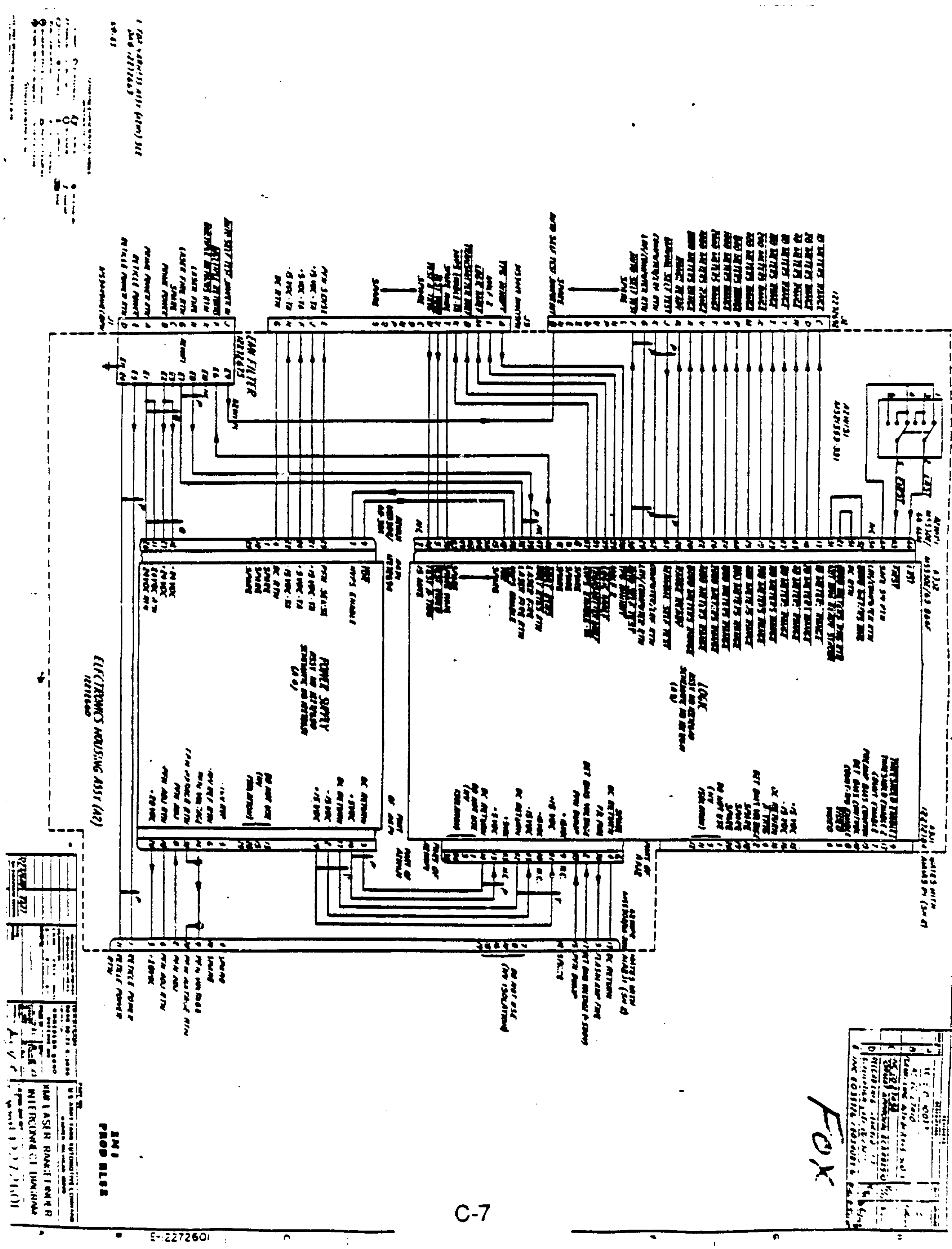
4.2.1.3.6 Output data lines. With the RANGE switch in either the ARM FIRST RTN or ARM LAST RTN position and the laser output covered (NOTE: PFN must be charged), apply the signals specified in 3.2.1.3.6. Verify that the requirements of of 3.2.1.3.6 are met. (NOTE: The LRF has a built-in range output of ± 10 meters, so the test may require repetition.)

4.2.1.4 Range accuracy. Aim the LRF at a target of a range known to within one meter (Item 4.1, Table I). Perform the ranging operation of 4.2.1.5.1. Verify that the requirement of 3.2.1.4 is met.

4.2.1.5 Duty cycle

4.2.1.5.1 Continuous pulse rate. [The following test shall be performed with a 1.5 db ±20 percent filter (3.0 db 2-way) placed in front of the objective lens at an angle of 2° - 5° from the normal to the beam axis.] With the RANGE switch set in the ARM LAST RTN position, perform 30 ranging operations in accordance with 4.1.4.[illegible]c at interpulse period intervals of 20 (+2, -0) seconds. Verify that valid range data are received for all ranging operations and that the requirements of 3.2 1.5.1 are met.

4.2.1.5.2 Four pulses maximum rate. With the RANGE switch set in ARM LAST RTN position, perform four ranging operations in accordance with 4.1.4.[illegible].c at interpulse period intervals of 2.0 ±0.1 seconds against a target of known range within the range window of 200 to 7990 meters. Wait 148 ±2 seconds and repeat four ranging operations at the same rate. Verify that valid range data is received for each ranging operation and that the requirement of 3.2.1.5.2 is met.


ELECTRONICS HOUSING ASSY (A2)
POWER SUPPLY
LOGIC
EMI FILTER
FOX
E-2272601

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Appendix D - Ft. Knox Weather Report

SURFACE WEATHER OBSERVATIONS (AIRWAYS)

LATITUDE	LONGITUDE	STATION ELEVATION (H_p) Feet (MSL)	TIME CONVERSION GMT to LST	MAG to TRUE	DAY (LST)	MONTH	YEAR	STATION (or grid coord) & STATE or COUNTRY
		+[illegible]	+/- 5 Hrs	+ ( ) Deg	5	JAN	1989	[illegible]

TYPE (1)	TIME ( ) (2)	SKY CONDITION (3)	PVLG VSBY (miles) (4)	WEATHER AND OBSTRUC TO VISION (5)	SEA LEVEL PRES (mb) (6)	TEMP (°F) (7)	DEW-POINT (°F) (8)	WIND DRCTN (true) (9)	WIND SPEED (knots) (10)	WIND CHARACTER (knots) (11)	ALSTG (inches) (12)	REMARKS AND SUPPLEMENTARY CODED DATA (All times GMT. Desired order of entry: SFC based obsc phenomena, other remarks elaborating on preceding coded data, coded additive data groups, radiosonde data, runway conditions, weather modification.) (13)	STATION PRESSURE (inches) (17)	TOTAL SKY COVER (21)	OB IN (22)
[illegible]	1443	120 SCT 250 SCT	7			39	31	E22	01		E017	MMM 1014	E29.360	2	M
SP	1521	55 SCT 120 SCT 250 SCT	7			42	34	E22	04		E011		E29.300	3	M
A	1555	55 SCT 120 SCT 250 SCT	7			43	34	E19	04		E001		E29.210	5	M
SA	1655	55 SCT E120 BKN 250 BKN	7			47	17	E22	05		E001		E29.310	9	M
SP	1730	55 SCT E120 BKN 250 OVC	7			49	14	E23	01		E995		E29.300	9	M
SA	1755	55 SCT E120 BKN 250 BKN	7			49	22	E21	02		E997	MMM 1518	E29.210	9	M
SP	1835	55 SCT E100 BKN 250 BKN	7			52	22	E17	03		E991		E29.210	9	M
A	1905	55 SCT E90 BKN 120 OVC	7			54	23	E17	05		E989		E29.190	10	[illegible]
SP	1951	55 SCT E90 BKN 120 OVC	7			52	23	E19	07	G11	E968		E29.165	10	[illegible]

AWS FORM APR 75 10b PREVIOUS EDITION WILL BE USED.